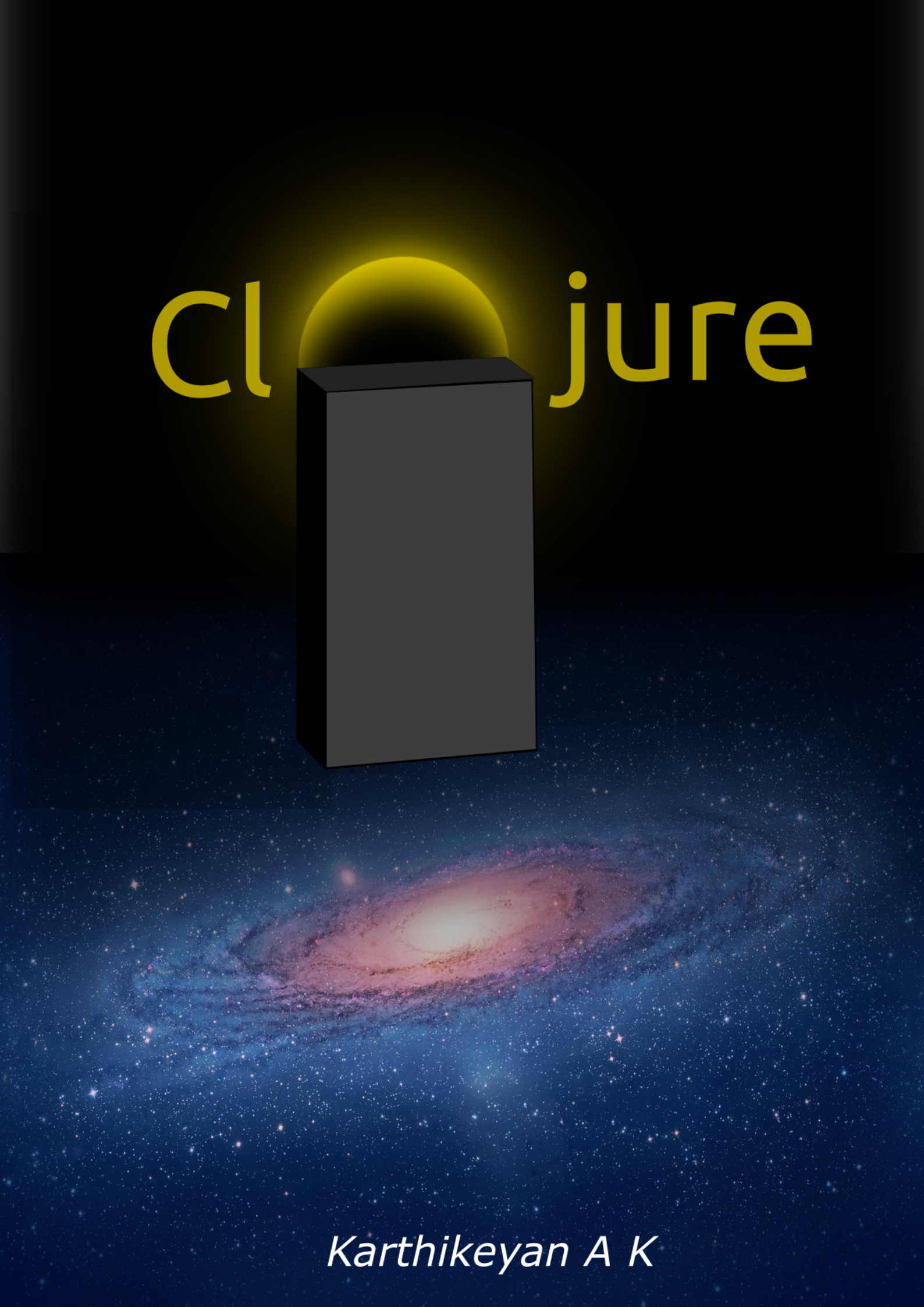
Clojure



Karthikeyan A K

Clojure

Karthikeyan.A.K

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Prerequisite

There is one thing though, you must be familiar with using computers. I would suggest one to be familiar with Ubuntu GNU/Linux, you can get it here https://ubuntu.com. Install it on a computer, learn to use it, and get familiar with GNU/Linux. To get familiar with GNU/Linux one may visit and learn from http://linuxjourney.com.

Why this book?

For unknown reason very smart programmers are using Clojure, I haven't figured out why. The writing of this book is to figure out why. My last job was in a medical coding company where we maintained 3 Rails app, I got to code in two of them, one had 0.1+ million lines of code, was headed by a guy who knew how to code and was maintained okay, other one had 0.2+ million lines of code, had no test, headed by a guy who did not know how to code but could just do politics, that project was headed by people who did not know how to write maintainable software and senior developers in the project had to bear the brunt of history. It showed me how screwed Rails app can get if left unattended, so I want to search for something that's more idiot-proof.

When I first met Ruby on Rails, I was very sure PHP will be the king of web page making, and it's true even today, but Rails changed my life and made me more productive. I will not say that with Rails we cannot handle massive projects, in my present job extremely skilled people and me are doing just that, but then this book is just a search, a very similar search I did in my PHP days when I got a hint of the power of Ruby, and this book is to document my search, to see if Clojure is good enough or not.

Another reason why I am going into Clojure is because of Clojure Script. If I can use the same language on both client and server side and if its not dreaded JavaScript, who wouldn't want to explore such language? Lisp seems to be a very old language and Clojure seems to be a Lisp dialect for the present day. Somehow the inventors of Lisp seem to have struck the right balance early on, and I need to find out what it is.

I have lots of Data Science ideas, and looks like Clojure is fast and powerful enough to be used in those fields too (at least for personal use). I want to explore that too, though I wonder if JVM ever runs on GPU for fast computation.

One negative I find is JVM. Java is controlled by Oracle, and it's an evil enterprise like Microsoft and Apple. That's the only negative I have, but let's see how things go.

Where to get help

If you are new to programming, or even if you are a seasoned programmer, chances are you could be stuck and may need help from time to time. For Clojure people these channels listed in this chapter may help.

Local communities

Its better to search for local Clojure and GNU/Linux communities and become friends with them. If you can find one, consider joining them. Those are the best ways to get help. One may look here https://clojure.org/community/user_groups for nearby group.

Clojure website

The Clojure website may be a good starting point to browse for help if you have the time and patience. One may visit it here https://clojure.org/.

Clojure forum

The official Clojure forum is here https://ask.clojure.org/, one may join it and start asking questions. Some of my initial doubts were cleared by this forum.

Clojure has a second forum here https://clojureverse.org/, it's called Clojureverse this one too seems to be popular.

Reddit

Reddit also has a Clojure community. If you are a reddit user, one may find the community here https://www.reddit.com/r/Clojure/.

Getting this book

One can get this book here https://clojure-book.gitlab.io/.

Chapter 1. Installing Stuff

Watch the video for this section here: https://yu7.in/clj-installing-stuff

1.1. Clojure

Clojure works on all operating systems. You can install Clojure by following the link here: https://clojure.org/guides/install_clojure. Once installed, it is time for us to check the Clojure REPL. (To learn what a REPL is, check out https://en.wikipedia.org/wiki/Read%E2%80%93eval%E2%80%93print_loop). Type `clj` in your terminal, and you should see something like this:

```
$ clj
Clojure 1.10.2
user=>
```

That's the Clojure REPL. Now type `(println "Hello World")` in it as shown below and press `ENTER`.

```
$ clj
Clojure 1.10.2
user=> (println "Hello World")
```

You will see `Hello World` printed out as shown:

```
$ clj
Clojure 1.10.2
user=> (println "Hello World")
Hello World
nil
user=>
```

There is also a `nil` after `Hello World`. Don't worry too much about that; we will see what that is later. After the `nil`, you will see `user=>` once again, which means Clojure is waiting for you to type another command for it to execute.

If you want to exit the Clojure REPL, press `CTRL` + `D`. You will get back to your terminal prompt.

1.2. Leiningen

Leiningen is a tool that automates tasks like setting up a Clojure project. Please refer to its website https://leiningen.org/ and install it. Once installed, type `lein repl` in your terminal, and you should see this:

```
$ lein repl
nREPL server started on port 64285 on host 127.0.0.1 - nrepl://127.0.0.1:64285
REPL-y 0.4.4, nREPL 0.8.3
Clojure 1.10.1
OpenJDK 64-Bit Server VM 1.8.0_152-release-1056-b12
    Docs: (doc function-name-here)
          (find-doc "part-of-name-here")
  Source: (source function-name-here)
 Javadoc: (javadoc java-object-or-class-here)
    Exit: Control+D or (exit) or (quit)
 Results: Stored in vars *1, *2, *3, an exception in *e

user=>
```

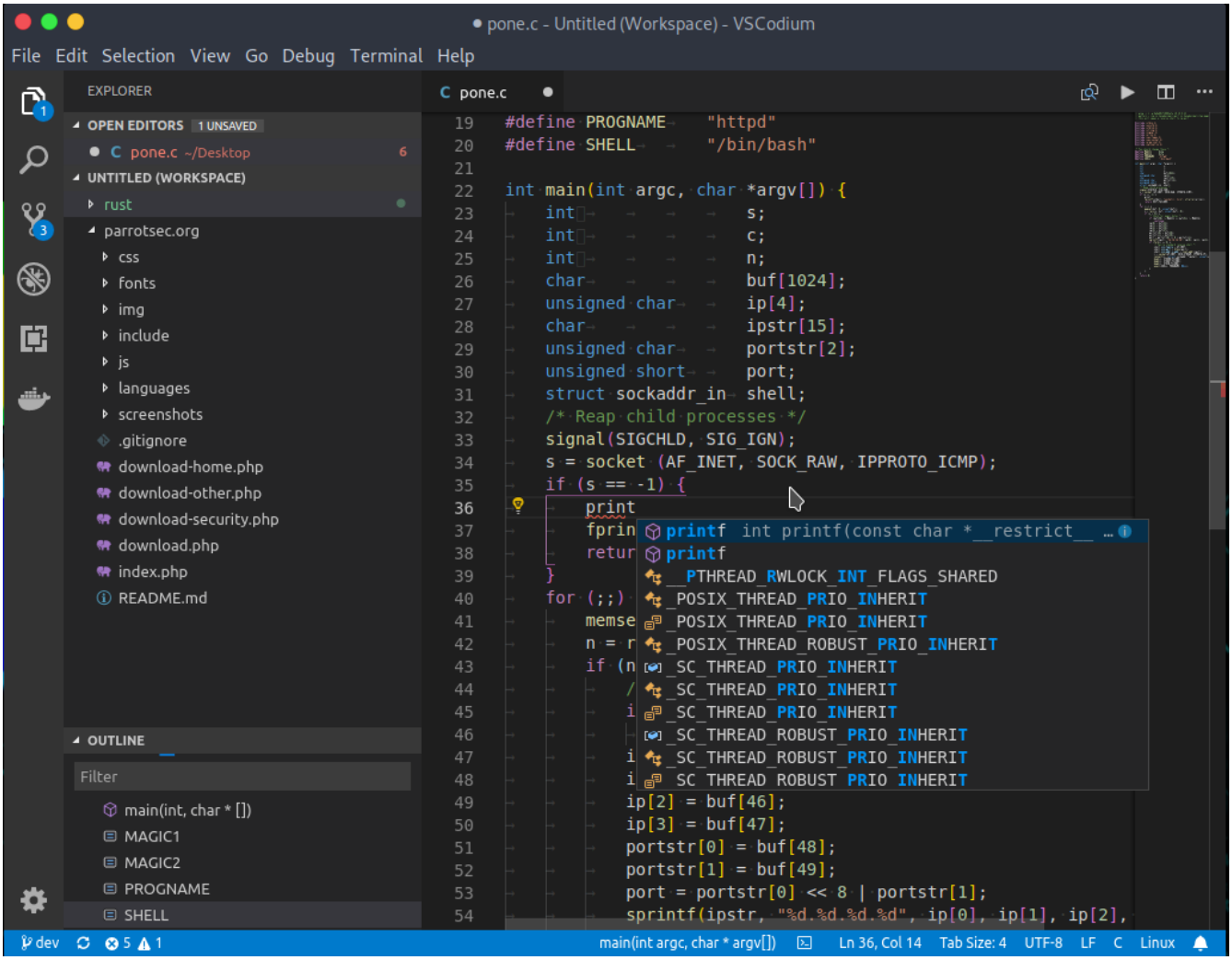
Press `CTRL` + `D` to exit. All is well, and you have successfully installed Leiningen.

Open or create the file `~/.lein/profiles.clj` and add the following content to it:

```
{:repl {:plugins [[cider/cider-nrepl "0.47.0"]]}}
```

1.3. Configuring IDE

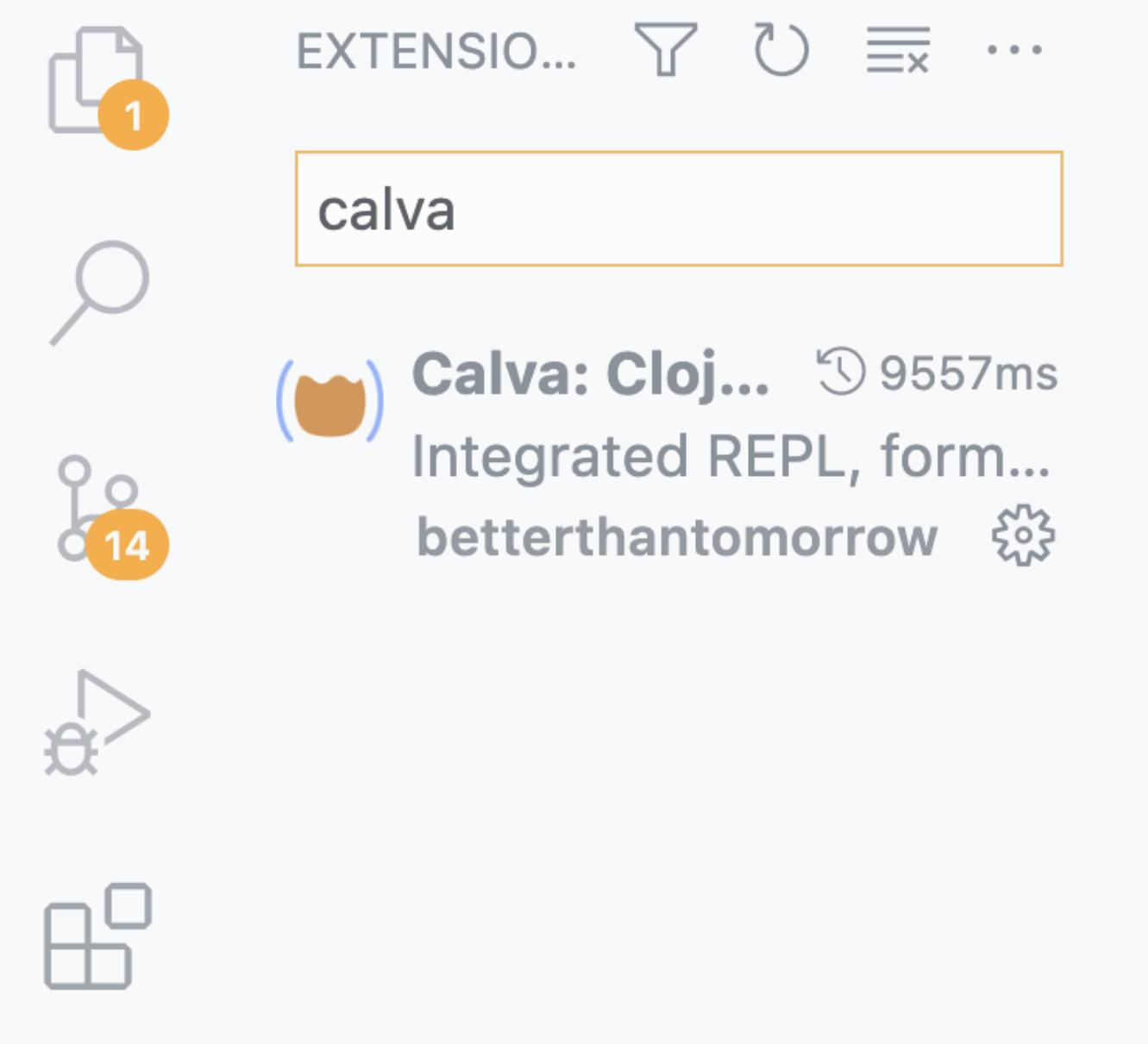
1.3.1. Installing VSCodium



You could use any IDE, but since this is my book, I will take the liberty of suggesting VSCodium. This IDE takes the editor made by Microsoft and removes the telemetry and tracking. You can get the IDE and find installation instructions at https://vscodium.com/.

1.3.2. Calva

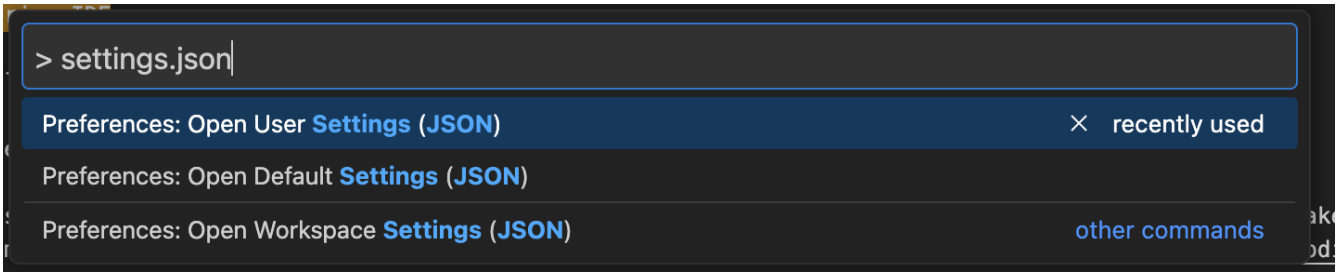
To use Clojure in VSCodium, there is an excellent extension called Calva. You can learn about it at https://calva.io. Go to VSCodium extensions and install it by searching for it:



You can get started with Calva with the excellent guides and videos at https://calva.io/getting-started/.

1.3.3. Modify user settings JSON

In VSCodium, open the user settings JSON file by pressing `CTRL` + `SHIFT` + `P` (or `CMD` + `SHIFT` + `P` on macOS) and type "settings json". You should see options like this:



Select `Preferences: Open User Settings (JSON)` and press `ENTER`. You will see a JSON file with content similar to this:

```
{
    "git.confirmSync": false
}
```

Add the following settings:

```
"calva.outputDestinations": {
   "evalResults": "repl-window",
   "evalOutput": "repl-window"
}
```

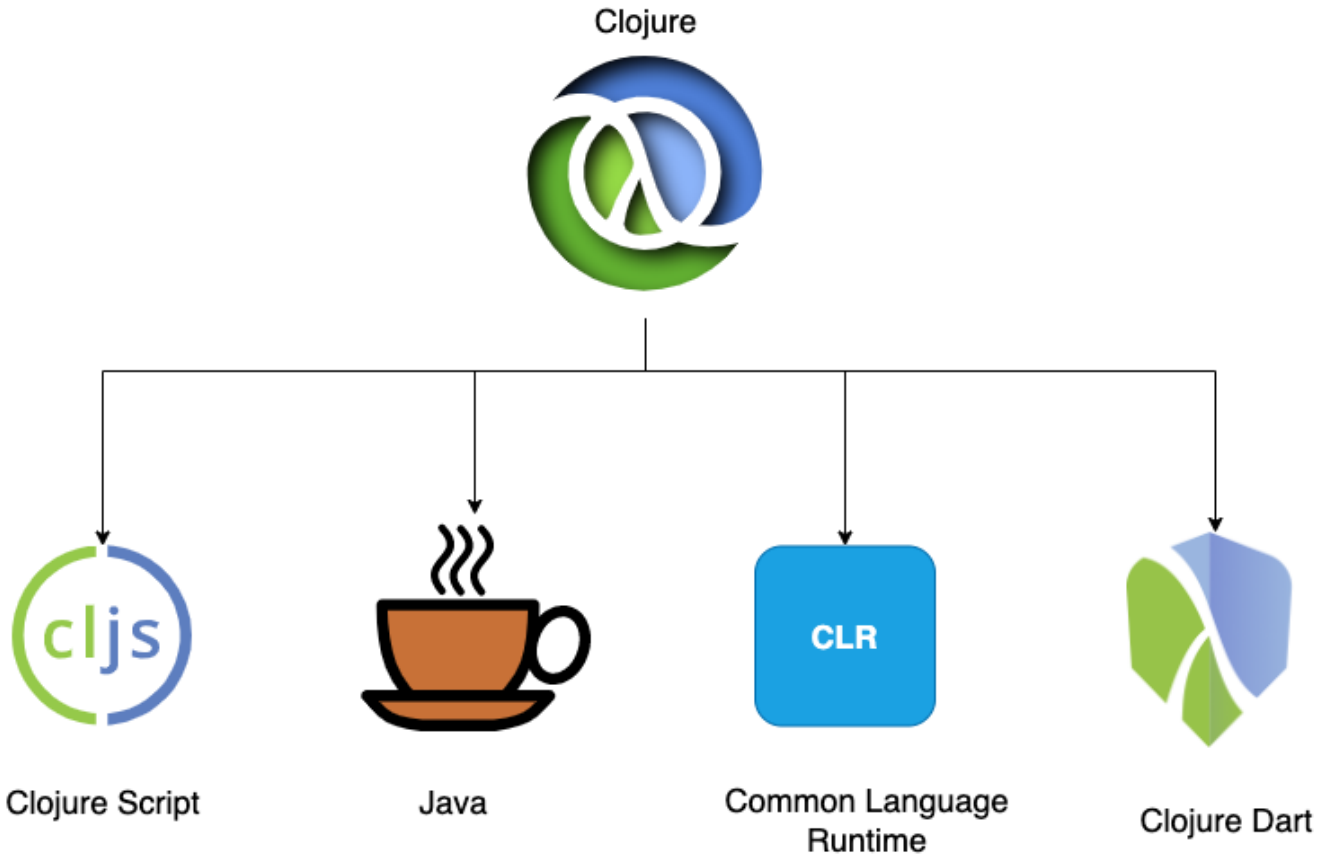
to the end of the JSON object, so it looks like this:

```
{
    "git.confirmSync": false,
    "calva.outputDestinations": {
        "evalResults": "repl-window",
        "evalOutput": "repl-window"
    }
}
```

Save it. You are all set.

Chapter 2. Hosted Language

Watch the video for this section here: https://yu7.in/clj-hosted-language



Clojure is a hosted language, which means it is not compiled directly to machine code that runs on a processor or an operating system. Clojure was initially designed to run on the Java Runtime Environment (JRE), compiling to JVM bytecode. Since Clojure is hosted, developers found ways to compile Clojure to JavaScript, which led to the creation of ClojureScript (https://clojurescript.org/). Clojure can also compile to the Common Language Runtime (https://clojure.org/about/clojureclr)—the target environment for the .NET family of languages. Additionally, it compiles to Dart via ClojureDart (https://github.com/Tensegritics/ClojureDart). Thus, by learning Clojure, one can target multiple platforms.

Note that Clojure does not promise "Write Once, Run Anywhere" (WORA) like Java does. Instead, you may need to modify your code when targeting different platforms. What you do get, however, is a uniform Clojure syntax across all of them.

As a web developer, I can write the backend in any language I like, but for the frontend, I am often forced to use JavaScript. With Clojure, however, I can write both the frontend and backend in Clojure, avoiding the cognitive load that comes with switching languages.

Chapter 3. First Steps

3.1. REPL

When I first started studying Clojure, I was introduced to REPL-driven development. I didn't understand what it was in my early days; even if you don't get it yet, don't worry, you eventually will. In this section, let's get a taste of REPL-driven development.

3.1.1. REPL in Terminal

In your terminal, type `clj` and you will see something like this:

```
$ clj
Clojure 1.11.1
user=>
```

The `Clojure 1.11.1` indicates that Clojure version 1.11.1 is installed on your machine, and `user=>` is the prompt where Clojure is waiting for your input. Type `(println "Hello World")` as shown and press Enter:

```
$ clj
Clojure 1.11.1
user=> (println "Hello World")
Hello World
nil
user=>
```

You will see the output `Hello World` followed by `nil`. Then, you are prompted again at `user=>`.

You can now press `CTRL` + `D` to exit the REPL.

So what actually happened when you typed `clj`? First, Clojure prompted you with `user=>`. After you entered the code and pressed `Enter`, the Clojure REPL **R**ead and **E**valuated it, determined that you wanted to print `Hello World`, **P**rinted `Hello World` (and the return value `nil`), and then **L**ooped back to the prompt `user=>`.

3.1.2. REPL in VSCodium

We have seen the REPL in action in the terminal; now let's see it in VSCodium. Create a folder named `code` and open it with VSCodium. Now create a file named `hello_world.clj` in it with the following content:

hello_world.clj

```
;; hello_world.clj
```

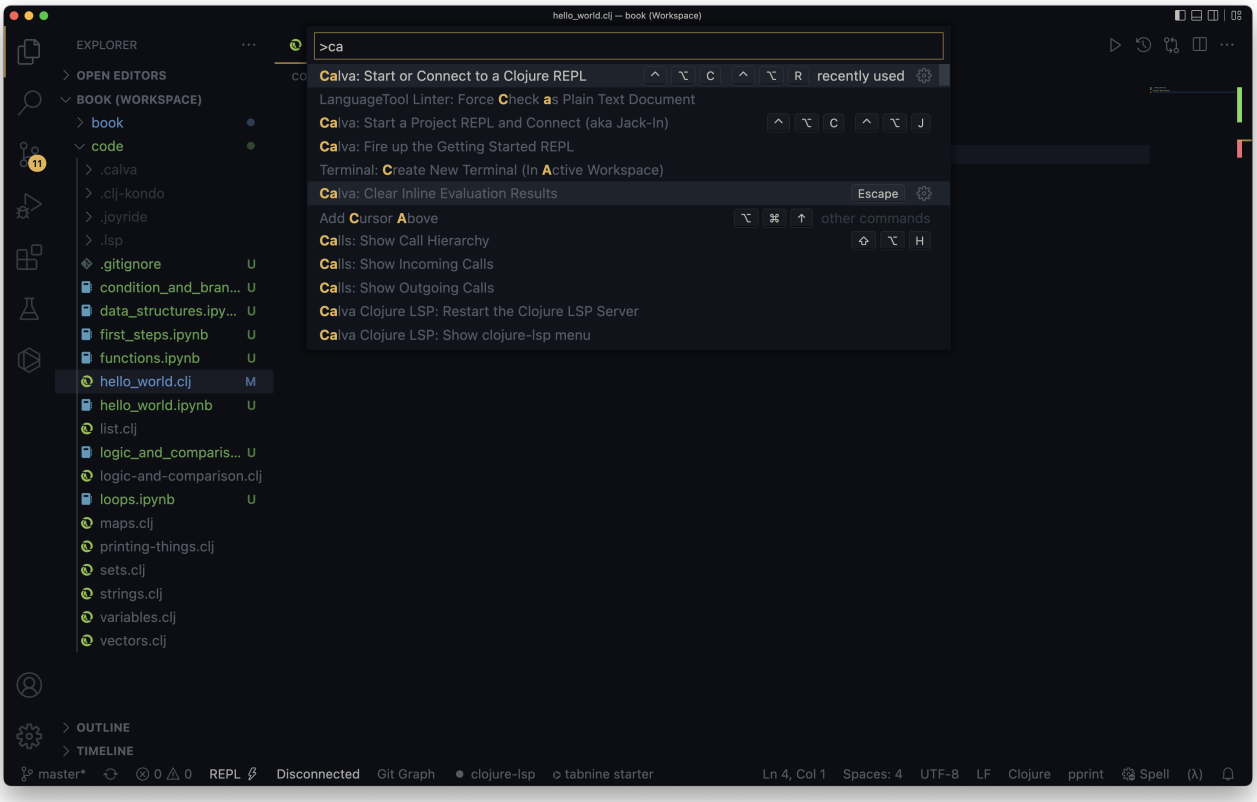
```
(println "Hello World")
```

Now in terminal `cd` into `code/` and type `lein repl`

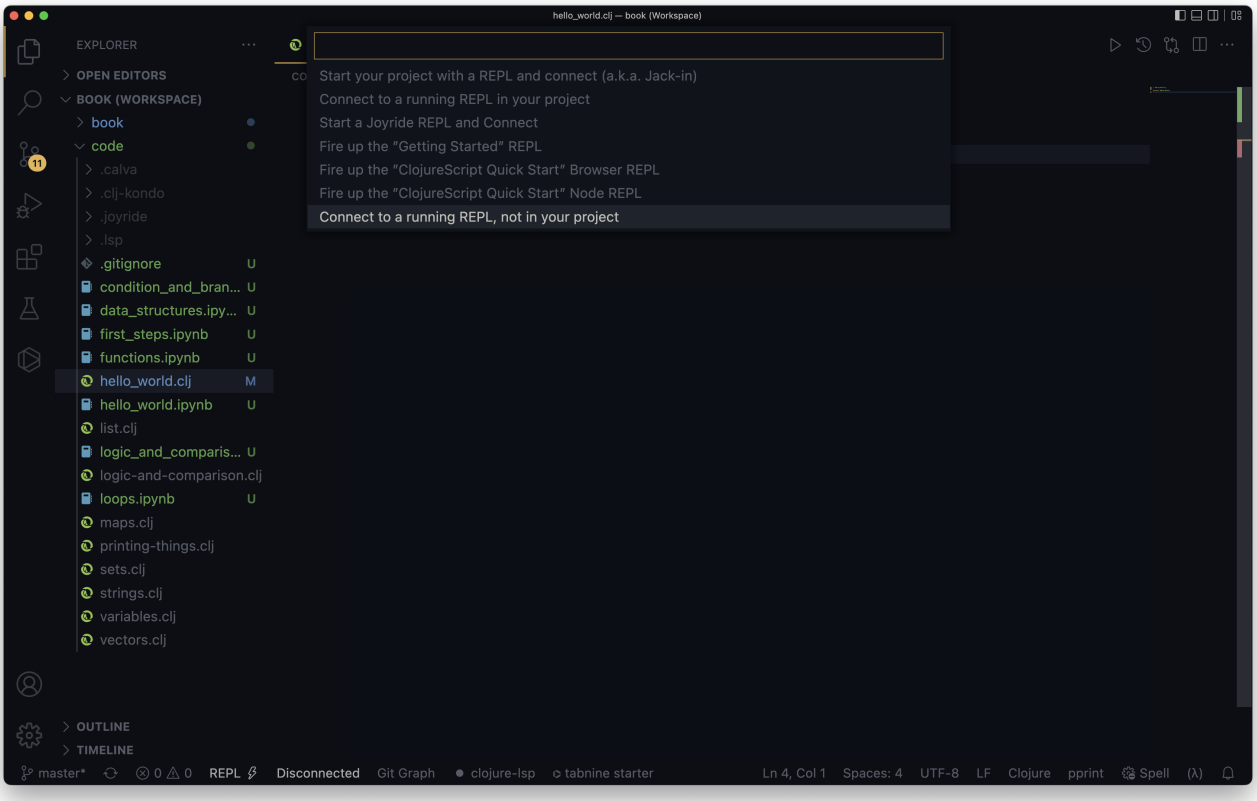
```
$ lein repl
nREPL server started on port 52897 on host 127.0.0.1 - nrepl://127.0.0.1:52897
REPL-y 0.4.4, nREPL 0.8.3
Clojure 1.10.1
OpenJDK 64-Bit Server VM 1.8.0_152-release-1056-b12
    Docs: (doc function-name-here)
          (find-doc "part-of-name-here")
  Source: (source function-name-here)
 Javadoc: (javadoc java-object-or-class-here)
    Exit: Control+D or (exit) or (quit)
 Results: Stored in vars *1, *2, *3, an exception in *e

user=>
```

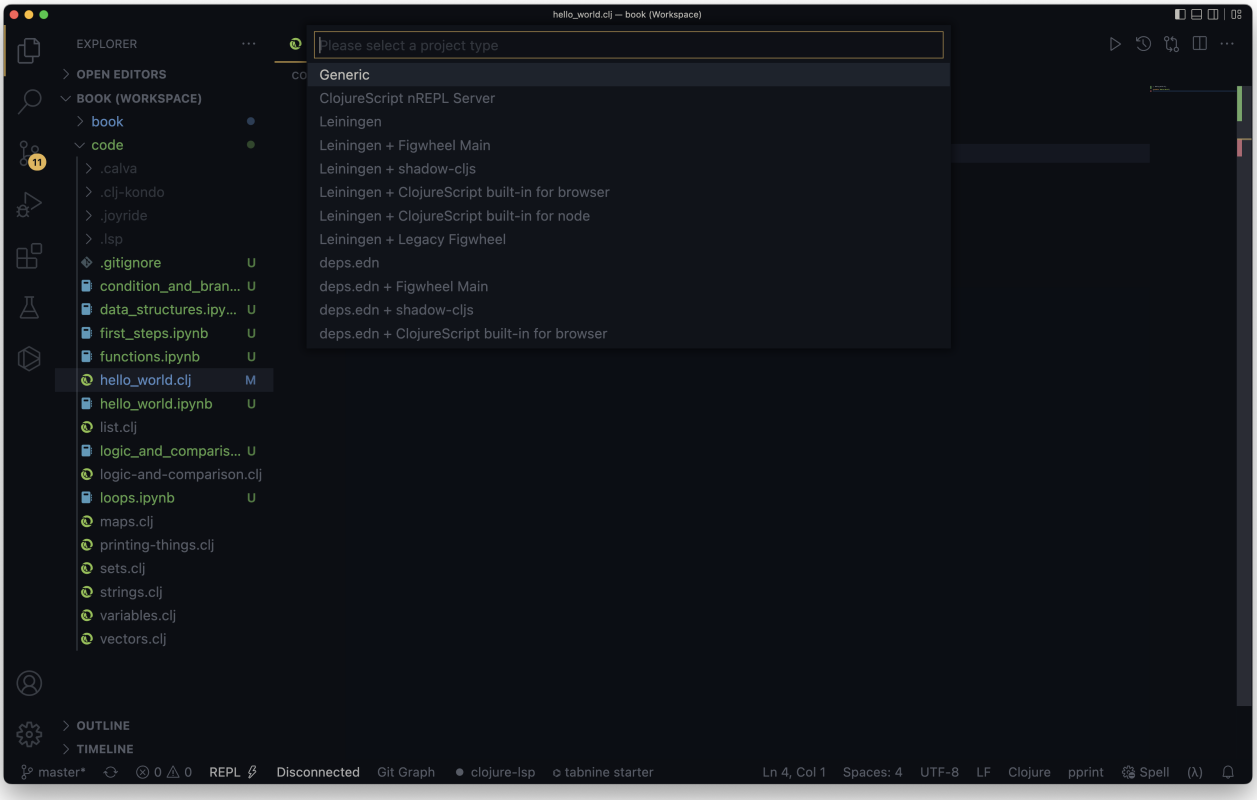
`lein` is short for Leiningen; you might remember installing it and checking if it launched. The `repl` command tells `lein` to start a REPL. You will see output similar to what is shown above. Note the `nrepl://127.0.0.1:52897` in the output; this means a REPL server is running at IP 127.0.0.1 [1] on port [2] 52897. Note down `127.0.0.1:52897`. The port number may vary in your case.



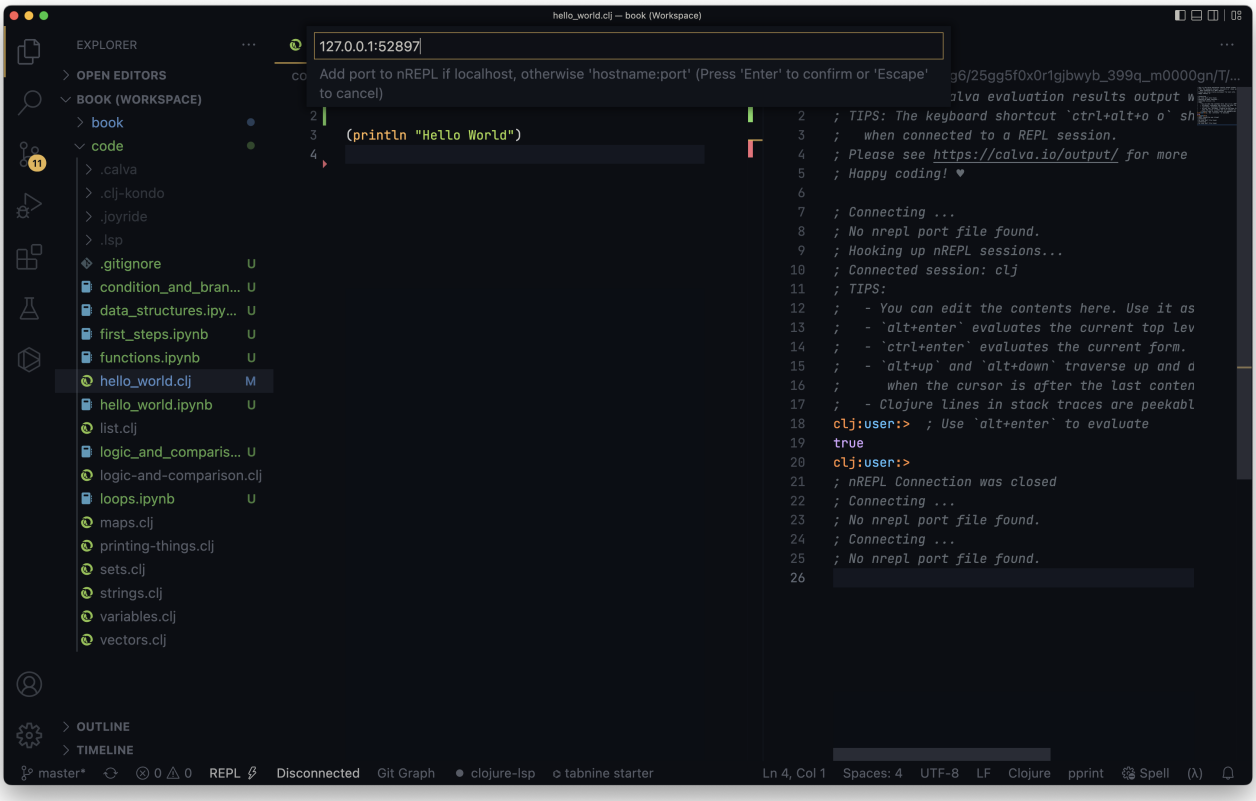
In VSCodium, press `CTRL` + `P` if you are on GNU/Linux, or `command` + `P` if you are on Mac and type `>`, which allows you to enter commands for VSCodium to execute. Try typing `Calva: Start or connect to a Clojure REPL`. As you type, VSCodium will suggest the option; press `ENTER` or click it.



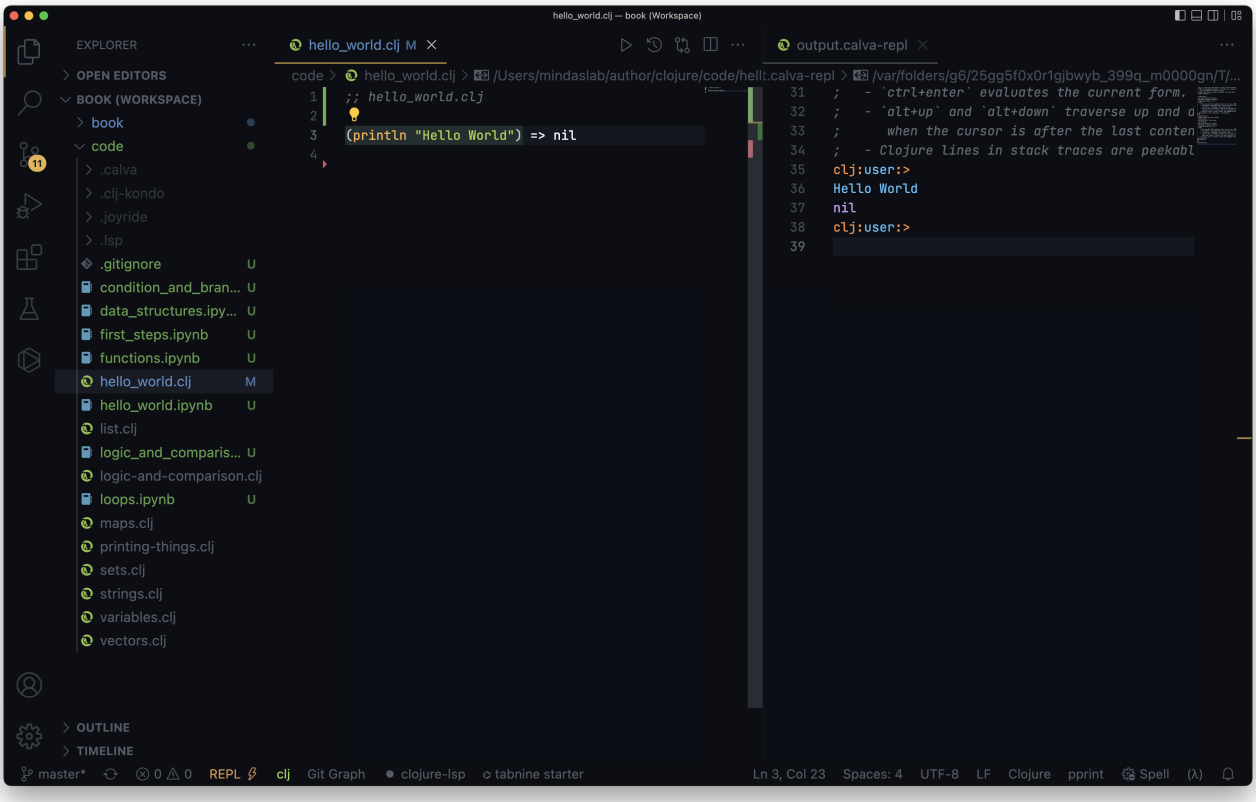
VSCodium will present another menu; select `Connect to a running REPL, not in your project`.



From the options, select `Generic`. You will then be prompted for the IP and port number where your REPL is running.



Paste the value `127.0.0.1:52897` and press Enter. A Clojure REPL window will open on the right. Now, in the `hello_world.clj` file on the left, place your cursor inside `(println "Hello World")` and press `ALT` + `ENTER` or `option` + `return`.



You will see the result of `(println "Hello World")` in the right-hand REPL pane. Congratulations,

you've learned how to connect a REPL with VSCodium.

3.2. Printing Things

Watch video for this section here https://yu7.in/clj-first-steps-printing-things

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/printing_things.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

First, let's print `Hello World!`. Copy the code below, paste it, and execute it:

```
(println "Hello World!")
```

Output

```
Hello World!
nil
```

You will see `Hello World!` followed by `nil` on the next line. For now, you can ignore `nil`; we will discuss it when we cover functions. For this task, our mission is accomplished.

Commenting is essential in coding. Comments are notes for the developer reading the code, and the computer ignores them during execution. In Clojure, everything that follows a semicolon `;` is a comment. So in the code below:

```
(println "Hello World!") ; Says Hello to this world
```

Output

```
Hello World!
nil
```

`; Says Hello to this world` is a comment that the Clojure interpreter ignores. In the code above, we are adding a comment on the same line as the code; by convention, a single semicolon `;` is used for this purpose. If you want a whole line dedicated to a comment, use two semicolons `;;` as shown below:

```
;; This program says hello to this world
(println "Hello World!")
```

Output

```
Hello World!
nil
```

Both single and double semicolons function the same way, but this is the established convention in Clojure for inline comments versus dedicated comment lines.

We have printed `Hello World`, but what if we want to print multiple things? With `println`, it is simple: just provide additional arguments, and it will print them as shown:

```
(println "Hello World!" "Try staying cool.")
```

Output

```
Hello World! Try staying cool.
nil
```

So you have successfully printed something in Clojure.

3.3. Arithmetic

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/arithmetic.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Watch the video for this section here: https://yu7.in/clj-arithmetic

In this section, let's explore mathematics in Clojure. First, let's add two numbers, 40 and 2:

```
(+ 40 2)
```

Output

```
42
```

In the expression above, we use the plus `+` symbol (which is actually a function in Clojure). We pass 40 and 2 as arguments to this function, which adds them and returns 42. Similarly, let's see what happens when we pass 44 and 2 to the minus `-` symbol:

```
(- 44 2)
```

Output

```
42
```

It subtracts the second argument, 2, from 44 and returns 42.

Now, let's see what happens when we pass 6 and 7 to the asterisk * operator:

```
(* 6 7)
```

Output

```
42
```

It returns 42, which is the product of 6 and 7.

Now, let's see what happens when we pass 210 and 5 to the slash / operator:

```
(/ 210 5)
```

Output

```
42
```

210 is divided by 5, resulting in 42.

Now, let's see what happens if we pass more than two numbers to the + function:

```
(+ 1 2 3 4 5)
```

Output

```
15
```

All the numbers are added together, and the sum is returned.

Look at the code below; can you figure out how it works?

```
(/ (+ 1 2 3 4 5) 5)
```

Output

```
3
```

Consider the expression `(/ (+ 1 2 3 4 5) 5)`. Focus on the innermost parentheses, `(+ 1 2 3 4 5)`, where several numbers are passed to the `+` function, which returns their sum: 15. Substituting 15 for `(+ 1 2 3 4 5)` gives us the expression `(/ 15 5)`, where 15 is divided by 5, resulting in 3.

Now, let's pass more than two arguments to `/`. For example, passing 1, 2, and 3 results in $\frac{1}{6}$:

```
(/ 1 2 3) ; this gives out a ratio, a Clojure data type
```

Output

```
1/6
```

The output above is a fraction (a ratio). To obtain a decimal result, append `.0` to at least one of the numbers passed to `/`:

```
(/ 1 6.0)
```

Output

```
0.16666666666666666
```

If this is unclear now, don't worry; it will be explained in more detail as you progress through the book.

As long as at least one number passed to `/` is a decimal (indicated by the `.` symbol), the result will be a decimal rather than a fraction:

```
(/ 1 2.0 3)
```

Output

```
0.16666666666666666
```

The same applies here:

```
(/ 1 2 3.0)
```

Output

```
0.16666666666666666
```

To get the quotient of a division, you can use the `quot` function:

```
(quot 14 5)
```

Output

```
2
```

To get the remainder of a division operation, use the `rem` function:

```
(rem 14 5)
```

Output

```
4
```

Let's calculate the area of a circle using Clojure. The area is πr^2, where π is approximately $\frac{22}{7}$. This can be coded as follows:

```
;; Let's calculate area of circle of radius 7 units
(* (/ 22 7) (* 7 7))
```

Output

```
154N
```

In this expression, π is represented by `(/ 22 7)` and r^2 (where r is 7) is represented by `(* 7 7)`. Multiplying these together results in `(* (/ 22 7) (* 7 7))`, with an output of `154N`.

The `N` indicates a BigInt (a way to store very large integers). Executing `(type 10N)` in the REPL returns `clojure.lang.BigInt`, whereas `(type 10)` returns `java.lang.Long`.

Adding `.0` to any of the numbers removes the `N`:

```
(* (/ 22 7) (* 7 7.0))
```

Output

```
154.0
```

Instead of using `(/ 22 7)` for π, we can use the Java `Math` library, as Clojure is hosted on the JVM. This allows Clojure to leverage powerful libraries provided by the host platform. We can replace `(/ 22 7)` with `Math/PI` as shown below:

```
(* Math/PI (* 7 7))
```

Output

```
153.93804002589985
```

Similarly, to compute x^y, we can use `Math/pow`. Replacing `(* 7 7)` with `(Math/pow 7 2)` looks like this:

```
(* Math/PI (Math/pow 7 2))
```

Output

```
153.93804002589985
```

3.4. Types of Numbers

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/types_of_numbers.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Watch video for this section here https://yu7.in/clj-num-types

There are different types of numbers in computing, just as there are different types of numbers in mathematics. For example, whole numbers are called `Long` in Clojure. You can verify this by passing a whole number to the `type` function, which tells you the type of data passed to it, as shown below:

```
(type 147)
```

Output

```
java.lang.Long
```

Numbers with decimal values are called `Double` in Clojure, as you can see below:

```
(type 147.67)
```

Output

```
java.lang.Double
```

The value of π is also a `Double` in Clojure:

```
(type Math/PI)
```

Output

```
java.lang.Double
```

If a `Long` (whole number) is divided by another `Long`, the result is a `Ratio` in Clojure:

```
(type (/ 84 32))
```

Output

```
clojure.lang.Ratio
```

As shown below, `(/ 84 32)` in Clojure does not provide a decimal value, but instead outputs a `Ratio`:

```
(/ 84 32)
```

Output

```
21/8
```

You can convert one type of number to another; for example, 32 is of type `Long`:

```
(type 32)
```

Output

```
java.lang.Long
```

you can convert it to a `Double` by passing it to the `double` function, as shown:

```
(double 32)
```

Output

```
32.0
```

When you query its type, it returns `Double`:

```
(type (double 32))
```

Output

```
java.lang.Double
```

If you want to prevent the division of two `Long`s from resulting in a `Ratio`, convert at least one of the arguments passed to the `/` function into a `Double`, as shown below:

```
(/ 84 (double 32))
```

Output

```
2.625
```

The result is a `Double` rather than a `Ratio`:

```
(type (/ 84 (double 32)))
```

Output

```
java.lang.Double
```

To get only the non-decimal part of a `Double`, pass that `Double` to the `long` function:

```
(long 42.32)
```

Output

```
42
```

As you can see, when a `Double` is passed to the `long` function, it is cast to a `Long`:

```
(type (long 42.32))
```

Output

```
java.lang.Long
```

3.5. Strings

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/strings.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Watch video for this section here https://yu7.in/clj-strings

Your very first Clojure program in this book was likely this:

```
(println "Hello World!")
```

It prints `Hello World!` on the screen. The text `"Hello World!"`, enclosed in double quotes, is a sequence of characters known as a string.

Anything enclosed in double quotes in Clojure is a `String`, as shown below:

```
(type "Hello")
```

Output

```
java.lang.String
```

Strings can be concatenated with other data types using the `str` function:

```
(str "1 + 2 is " (+ 1 2))
```

Output

```
"1 + 2 is 3"
```

In the code above, `(+ 1 2)` returns a `Long`, but it can be concatenated with the string `"1 + 2 is "` by passing both to the `str` function.

You can determine the number of characters in a string using the `count` function:

```
(count "Hello")
```

Output

```
5
```

In the code below, we pass six arguments to the `str` function: five numbers and a final string, `" and so on⋯"`:

```
(str 1 2 3 4 5 " and so on...")
```

Output

```
"12345 and so on..."
```

Clojure concatenates these values and returns a single string.

Clojure has a built-in string library; you can read the documentation at https://clojuredocs.org/clojure.string. Let's use the `reverse` function to reverse a string:

```
(clojure.string/reverse "Hello")
```

Output

```
"olleH"
```

Now, let's convert all characters to uppercase:

```
(clojure.string/upper-case "Hello")
```

Output

```
"HELLO"
```

This section provides a brief introduction to strings. You will learn more as you progress. Stay tuned!

3.6. Variables

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/variables.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Watch video for this section here https://yu7.in/clj-variables

Imagine variables as boxes that contain a value; they make the code more human-readable. For example, look at the code below:

```
(def my-name "Karthik")
```

Output

```
#'user/my-name
```

I have assigned the string `"Karthik"` to a variable named `my-name`. Now, `my-name` can be used anywhere in the Clojure code. When defining a variable, there are three main components. First, the parentheses:

```
 ()
```

Then we have the `def` function:

```
(def)
```

Following `def` is the variable name; in this case, it is `my-name`:

```
(def my-name)
```

The second argument to `def` is the value to be stored in `my-name`, which is `"Karthik"` in this example:

```
(def my-name "Karthik")
```

This is how we define a variable. A variable defined with `def` is typically called a global variable, meaning it is available anywhere in the program. If this isn't clear yet, don't worry.

Now we can print this variable as shown:

```
(println my-name)
```

Output

```
Karthik
nil
```

Here, I am adding `"Hello "` before the variable `my-name`, which is equivalent to using the string `"Karthik"`:

```
(println "Hello" my-name)
```

Output

```
Hello Karthik
nil
```

Look at the code below:

```
(def greeting (str "Hello " my-name "!"))
(println greeting)
```

Output

```
Hello Karthik!
nil
```

I have defined a variable called `greeting` and assigned it the result of `(str "Hello " my-name "!")`. This joins three strings—`"Hello "`, `my-name`, and `"!"`—and stores the result in `greeting`. Finally, we print it using `(println greeting)`.

Variables like `my-name` and `greeting` can be used anywhere in the code because they are defined using the `def` keyword. To define a local variable within a specific block `()`, use `let` as shown:

```
(let [local-variable "something"]
  (println local-variable))
```

Output

```
something
```

In the code above, we define a variable named `local-variable` with the value `"something"` and print it. However, outside the `(let ⋯)` block, this local variable does not exist, as shown below:

```
(println local-variable)
```

Output

```
; Syntax error compiling at (variables.clj:16:1).
; Unable to resolve symbol: local-variable in this context
```

Attempting to print `local-variable` results in an error.

3.7. Clojure in file

Watch video for this section here https://yu7.in/clj-in-file

Up until now, you have likely run your code in a REPL, either in your terminal or in an IDE (such as VSCodium). Now, let's see how to store your code in a file and run it. First, create a new file in your text editor named as follows:

hello_world.clj

```
;; hello_world.clj

(println "Hello World")
```

Save the code as `hello_world.clj`. Then, in your terminal, `cd` to the directory containing the file and run the following command:

```
$ clj hello_world.clj
```

The entire program will run, and you will see `Hello World` as the output. It should look like this:

```
$ clj hello_world.clj
WARNING: Implicit use of clojure.main with options is deprecated, use -M
Hello World
```

[1] https://en.wikipedia.org/wiki/Localhost

[2] https://en.wikipedia.org/wiki/Port_(computer_networking)

Chapter 4. Data Structures

Almost every programming language offers some way to pack, organize, and access data in a computer's RAM [1]. This relieves programmers from the burden of writing extensive code to manage data stored in the computer's temporary memory.

Strings are also data structures. They enable us to represent any written language in a computer's memory and help us perform operations on them. In this section, we will explore other data structures that Clojure provides, which you can use out of the box.

4.1. Vectors

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/vectors.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Watch the video for this section here https://yu7.in/clj-vectors

Imagine a rack with many compartments; the first compartment is labeled 0, the second 1, and so on. You can put something into this rack and retrieve it if you know the compartment number, also known as the index. This is a real-world analogy for vectors.

Look at the code below:

```
[1 2 3 4] ; a very simple vector
```

Output

```
[1 2 3 4]
```

This is how you represent a vector in Clojure. It starts with an opening square bracket `[` and ends with a closing square bracket `]`; everything in between are the elements of the vector. In the above code, you have four elements: `1`, `2`, `3`, and `4`.

Another way to create a vector is to pass arguments to a function called `vector`, as shown below:

```
(vector 1 2 3)
```

Output

```
[1 2 3]
```

In the above code, we passed `1`, `2`, and `3` to the `vector` function, and we get the vector `[1 2 3]`.

So far, we have seen vectors created with numbers; in reality, you can create a vector with any type of value:

```
[1 true "Bashir"] ; vector containing multiple data types
```

Output

```
[1 true "Bashir"]
```

In the above code, we created a three-element vector with `1` (a Long), `true` (a boolean, which you will learn about soon), and `"Bashir"` (a String).

In the code below, we define a variable named `friends` and assign it a vector containing four names:

```
(def friends
    ["Ram" "Bashir" "Antony" "Buddha"])
```

Output

```
#'user/friends
```

Now let's see what the first element of the vector `friends` is. To do that, we pass `friends` to a function named `first`:

```
(first friends)
```

Output

```
"Ram"
```

This returns the first element of the vector.

There is a function called `rest` which, when given a vector, omits the first element and returns the rest of the elements in the vector, as shown below:

```
(rest friends)
```

Output

```
("Bashir" "Antony" "Buddha")
```

As you can see, `"Ram"` is ignored because it is the first element, and the rest is returned.

Let's check the type of `friends`:

```
(type friends)
```

Output

```
clojure.lang.PersistentVector
```

From the output, it is clear that it's a vector, but let's check what type `rest` returns:

```
(type (rest friends))
```

Output

```
clojure.lang.PersistentVector$ChunkedSeq
```

Although it seems to return `("Bashir" "Antony" "Buddha")` (not enclosed in square brackets), querying the type reveals it is a chunked sequence of the passed-in vector.

We can access any element by its index in the vector using the `nth` function, whose first argument should be a vector and the second should be the index number, as shown:

```
(nth friends 3)
```

Output

```
"Buddha"
```

At index `3` of `friends`, the value is the string `"Buddha"`.

The element at the third index can also be accessed as shown:

```
(friends 3)
```

Output

```
"Buddha"
```

It seems that when you define `friends` as a vector, Clojure allows you to use `friends` as a function

that takes an index and returns the value at that position.

To add an element to the end of a vector, use the `conj` function, which takes a vector as the first argument and the value to be added as the second:

```
(conj friends "Periyaar")
```

Output

```
["Ram" "Bashir" "Antony" "Buddha" "Periyaar"]
```

In the above code, we added `"Periyaar"` to `friends`, but this does not mean that `friends` has been modified. We can print `friends`:

```
(println friends)
```

Output

```
[Ram Bashir Antony Buddha]
nil
```

And it still shows the original values without `"Periyaar"`. In reality, Clojure constructs and returns a new vector when we call `(conj friends "Periyaar")`.

To add an element to the beginning of a vector, use `cons` as shown below:

```
(cons "Periyaar" friends)
```

Output

```
("Periyaar" "Ram" "Bashir" "Antony" "Buddha")
```

Does it modify `friends`? Research the concept of immutability [2] in computing.

4.1.1. Exercise

- How do you get the total number of elements in a vector?
- What will happen if I give `(friends 42)`?

4.2. Lists

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/

master/list.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Watch the video for this section here https://yu7.in/clj-lists

Lists are very similar to vectors. The primary difference is that vectors are enclosed in square brackets `[` and `]`, while lists are enclosed in round parentheses `(` and `)`. In fact, an entire Clojure program is a list. For example, to calculate 3 + 5 in Clojure, we write `(+ 3 5)`. Because it is wrapped in round parentheses, it is a list.

All Clojure code consists of lists. A list starts with an opening parenthesis `(` and is typically followed by a function to call. For instance, to add two numbers, we use the `+` function. This starts as `+(`, followed by the arguments passed to the function—such as 3 and 5—resulting in `(+ 3 5`. Finally, a closing parenthesis `)` completes the list: `(+ 3 5)`, which can then be executed by the Clojure interpreter.

Take a look at the example below:

```
'(1 2 3 4)
```

Output

```
(1 2 3 4)
```

In the example above, we have built a list of four numbers. However, notice that we do not start with a `(`, but with an apostrophe followed by a parenthesis, like this: `'(`. This tells Clojure not to execute the content within the parentheses.

When you try it without an apostrophe, Clojure assumes `1` is a function and that `2`, `3`, and `4` are the arguments passed to it. It then tries to execute it and fails, as shown below:

```
(1 2 3 4)
```

Output

```
; Execution error (ClassCastException) at lawyer/eval2148 (REPL:79).
; class java.lang.Long cannot be cast to class clojure.lang.IFn (java.lang.Long is in
module java.base of loader 'bootstrap'; clojure.lang.IFn is in unnamed module of
loader 'bootstrap')
```

The apostrophe before the parentheses tells Clojure not to execute `'(1 2 3 4)`, but rather to treat it simply as a list.

You can also create a list using the `list` function, as shown below:

```
(list 1 2 3)
```

Output

```
(1 2 3)
```

Above, we passed `1`, `2`, and `3` to the `list` function, and we get a list returned.

In the code below, we are creating a list of four strings and assigning it to a variable `friends-list`:

```
(def friends-list
    '("Ram" "Bashir" "Antony" "Buddha"))
```

Output

```
#'user/friends-list
```

Note how we are using the apostrophe in `'("Ram" "Bashir" "Antony" "Buddha")` to tell the Clojure interpreter not to execute the list.

Now let's see how many elements are in `friends-list`. To do that, we use `count` as shown below and pass `friends-list` to it:

```
(count friends-list)
```

Output

```
4
```

Thus, `count` indicates there are four elements in `friends-list`.

Let's get the first element in `friends-list`. For that, we use the `first` function as shown below:

```
(first friends-list)
```

Output

```
"Ram"
```

Now let's get all elements except the first one in `friends-list`. For that, we use the `rest` function as shown below:

```
(rest friends-list)
```

Output

```
("Bashir" "Antony" "Buddha")
```

Now let's get the fourth element in `friends-list`. For that, we use the `nth` function, which takes a list as the first argument and the index to be fetched as the second argument.

```
(nth friends-list 3)
```

Output

```
"Buddha"
```

Note that list indexing starts at zero. That is, the first element is indexed 0, the second is 1, and so on.

In the example below, let's try to get the fourth element of `friends-list` by passing the number 3 to it directly:

```
(friends-list 3)
```

Output

```
Execution error (ClassCastException) at user/eval5554 (REPL:1).
clojure.lang.PersistentList cannot be cast to clojure.lang.IFn

       core.clj:  3214 clojure.core$eval/invokeStatic
       core.clj:  3210 clojure.core$eval/invoke
       main.clj:   437 clojure.main$repl$read_eval_print__9086$fn__9089/invoke
       main.clj:   458 clojure.main$repl$fn__9095/invoke
       main.clj:   368 clojure.main$repl/doInvoke
   RestFn.java:  1523 clojure.lang.RestFn/invoke
       AFn.java:    22 clojure.lang.AFn/run
       AFn.java:    22 clojure.lang.AFn/run
   Thread.java:   745 java.lang.Thread/run
```

And it fails.

Now, let's add an element to the list. For that, we use the `conj` function. With `conj`, we pass the list to which the element should be added, followed by the element itself, as shown below:

```
(conj friends-list "Periyaar")
```

Output

```
("Periyaar" "Ram" "Bashir" "Antony" "Buddha")
```

4.3. Sets

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/sets.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Watch the video for this section here https://yu7.in/clj-sets

A set is a collection of unique items. Imagine a list or a vector where no two items repeat; that's a set. In Clojure, you can create a set as shown:

```
#{1 2 3 4}
```

Output

```
#{1 4 3 2}
```

A set starts with a hash symbol and an opening curly brace `#{`, followed by the set items, and ends with a closing curly brace `}`.

Below, we query the type of the set:

```
(type #{1 2 3 4})
```

Output

```
clojure.lang.PersistentHashSet
```

It returns `clojure.lang.PersistentHashSet`, which might be confusing to beginners. Instead, one can use the `set?` function to check if something is a set, as shown below:

```
(set? #{1 2 3 4})
```

Output

```
true
```

Since `#{1 2 3 4}` is a set, it returns `true`.

A set can have only unique elements. If we try to create a set with non-unique elements using a literal, it will throw an error, as shown:

```
#{1 2 3 4 4}
```

Output

```
Syntax error reading source at (REPL:1:13).
Duplicate key: 4

    PersistentHashSet.java:    68 clojure.lang.PersistentHashSet/createWithCheck
           LispReader.java:  1366 clojure.lang.LispReader$SetReader/invoke
           LispReader.java:   853 clojure.lang.LispReader$DispatchReader/invoke
           LispReader.java:   285 clojure.lang.LispReader/read
                  core.clj:  3768 clojure.core$read/invokeStatic
                  core.clj:  3741 clojure.core$read/invoke
                  main.clj:   433
clojure.main$repl$read_eval_print__9086$fn__9087/invoke
                  main.clj:   432 clojure.main$repl$read_eval_print__9086/invoke
                  main.clj:   458 clojure.main$repl$fn__9095/invoke
                  main.clj:   368 clojure.main$repl/doInvoke
               RestFn.java:  1523 clojure.lang.RestFn/invoke
                  AFn.java:    22 clojure.lang.AFn/run
                  AFn.java:    22 clojure.lang.AFn/run
               Thread.java:   745 java.lang.Thread/run
```

Let's create a set of unique fruit names:

```
#{"Apple" "Orange" "Mango" "Banana"}
```

Output

```
#{"Mango" "Orange" "Apple" "Banana"}
```

Now, when we try to create a similar set with a duplicate element, `"Apple"`, it throws an error, as shown below:

```
#{"Apple" "Orange" "Mango" "Banana" "Apple"}
```

Output

```
Syntax error reading source at (REPL:1:45).
Duplicate key: Apple

    PersistentHashSet.java:    68 clojure.lang.PersistentHashSet/createWithCheck
           LispReader.java:  1366 clojure.lang.LispReader$SetReader/invoke
           LispReader.java:   853 clojure.lang.LispReader$DispatchReader/invoke
           LispReader.java:   285 clojure.lang.LispReader/read
                  core.clj:  3768 clojure.core$read/invokeStatic
                  core.clj:  3741 clojure.core$read/invoke
                  main.clj:   433
clojure.main$repl$read_eval_print__9086$fn__9087/invoke
                  main.clj:   432 clojure.main$repl$read_eval_print__9086/invoke
                  main.clj:   458 clojure.main$repl$fn__9095/invoke
                  main.clj:   368 clojure.main$repl/doInvoke
               RestFn.java:  1523 clojure.lang.RestFn/invoke
                  AFn.java:    22 clojure.lang.AFn/run
                  AFn.java:    22 clojure.lang.AFn/run
               Thread.java:   745 java.lang.Thread/run
```

Let's create a set of fruit names and assign it to a variable named `fruits`, as shown below:

```
(def fruits #{"Apple" "Orange" "Mango" "Banana"})
```

Output

```
#'user/fruits
```

Now we can check if `fruits` contains `"Banana"`, as shown below:

```
(contains? fruits "Banana")
```

Output

```
true
```

It returns `true` because `fruits` contains `"Banana"`.

Now let's check if `fruits` contains `"Jack Fruit"`:

```
(contains? fruits "Jack Fruit")
```

Output

```
false
```

It returns `false` because `"Jack Fruit"` is not part of `fruits`.

You can also check if a set contains an element by using the set itself as a function, as shown below:

```
(fruits "Banana")
```

Output

```
"Banana"
```

In the code above, we pass `"Banana"` to `fruits`, and it returns `"Banana"` because it is present in the set.

When we pass `"Jack Fruit"` to `fruits`, it returns `nil` because `"Jack Fruit"` is not in the set:

```
(fruits "Jack Fruit")
```

Output

```
nil
```

Food for thought: if `(fruits "Banana")` works, does this suggest that Clojure has treated the set `fruits` as a function?

Now let's see what happens if we try to pass `fruits` to `"Banana"`, as shown below:

```
("Banana" fruits)
```

Output

```
Execution error (ClassCastException) at user/eval5624 (REPL:1).
java.lang.String cannot be cast to clojure.lang.IFn

       core.clj:  3214 clojure.core$eval/invokeStatic
       core.clj:  3210 clojure.core$eval/invoke
       main.clj:   437 clojure.main$repl$read_eval_print__9086$fn__9089/invoke
       main.clj:   458 clojure.main$repl$fn__9095/invoke
       main.clj:   368 clojure.main$repl/doInvoke
   RestFn.java:  1523 clojure.lang.RestFn/invoke
       AFn.java:    22 clojure.lang.AFn/run
       AFn.java:    22 clojure.lang.AFn/run
```

```
    Thread.java:   745 java.lang.Thread/run
```

It fails.

Clojure also has a special data type called keywords. Their syntax is a colon followed by a name, such as `:<some-name>`. For example, if we want a set of programming languages, we can define it as follows:

```
(def programming-languages #{:ruby :python :clojure})
```

Output

```
#'user/programming-languages
```

In this case, every element in `programming-languages` is a keyword.

Now let's check if `programming-languages` contains `:ruby`:

```
(contains? programming-languages :ruby)
```

Output

```
true
```

It does.

Now let's check if it contains `:java`:

```
(contains? programming-languages :java)
```

Output

```
false
```

It does not.

You can also check if an element exists in `programming-languages` by passing the element to the set:

```
(programming-languages :ruby)
```

Output

```
:ruby
```

Since `:ruby` is in `programming-languages`, it is returned.

Because `:ruby` is a keyword, it has special properties that strings do not have. Recall that attempting to check if `"Banana"` exists in `fruits` using `("Banana" fruits)` failed. However, checking if `:ruby` exists in `programming-languages` using the same pattern works, as shown below:

```
(:ruby programming-languages)
```

Output

```
:ruby
```

We can add an element to a set using the `conj` function. In this case, let's add `:perl` to `programming-languages`:

```
(conj programming-languages :perl)
```

Output

```
#{:clojure :python :perl :ruby}
```

Similarly, we can remove an element from a set using the `disj` function. Let's remove `:python` from `programming-languages`:

```
(disj programming-languages :python)
```

Output

```
#{:clojure :ruby}
```

That covers the basics of sets for now.

4.4. Maps

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/maps.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Watch the video for this section here https://yu7.in/clj-maps

Lists and vectors can be accessed using numeric indices, as shown in the following code:

```
(def nums ["zero" "one" "two" "three" "four" "five" "six"])

(nth nums 5)
```

Output

```
"five"
```

We get `"five"` as the output. But what if we want to use more user-friendly words as indices for our data collection? This is where maps come in.

Look at the code below, then type and execute it:

```
{ "name" "Bashir" "age" 12 }
```

Output

```
{"name" "Bashir", "age" 12}
```

In the above code, we create a map where the first element has the key `"name"` and the value `"Bashir"`, and the second element has the key `"age"` and the value `12`.

Instead of using curly braces, we can create a map by passing keys and values to the `hash-map` function, as shown below:

```
(hash-map "name" "Bashir"
          "age" 20)
```

Output

```
{"age" 20, "name" "Bashir"}
```

The `hash-map` function takes keys as odd-numbered arguments and values as even-numbered arguments. In the code above, `"name"` is mapped to `"Bashir"` and the key `"age"` is mapped to the value `20`.

Now, let's create a map and assign it to a variable named `friend`:

```
(def friend { "name" "Bashir" "age" 12 })
```

Output

```
#'user/friend
```

Now we can retrieve the value associated with the key `"name"` from `friend` using the `get` function, passing the map as the first argument and the key to be fetched as the second:

```
(get friend "name")
```

Output

```
"Bashir"
```

The code above looks for the key `"name"` in `friend`, and its corresponding value, `"Bashir"`, is returned.

There is also a shortcut to retrieve a value from a map: treat the map itself as a function and pass the key to it, as shown below:

```
(friend "name")
```

Output

```
"Bashir"
```

In the example above, we have the map `friend`; by passing the key `"name"` to it, we receive the mapped value `"Bashir"`.

The type of `"name"` is a string, as seen below:

```
(type "name")
```

Output

```
java.lang.String
```

Clojure also has keywords, which are preceded by a colon `:` followed by the keyword's name. As you can see below, `:name` is a keyword:

```
(type :name)
```

Output

```
clojure.lang.Keyword
```

Instead of using strings as keys, let's create a map with keywords as keys:

```
(def wise-friend {:name "Periyaar"
                  :age 90})
```

Output

```
#'user/wise-friend
```

In the code above, we create a map where the key `:name` is mapped to `"Periyaar"` and the key `:age` is mapped to `90`. We assign this map to `wise-friend`.

Now we can retrieve the `:name` of `wise-friend` as follows:

```
(wise-friend :name)
```

Output

```
"Periyaar"
```

Similarly, we can retrieve the `:age` of `wise-friend` as shown below:

```
(get wise-friend :age)
```

Output

```
90
```

In the above example, we use the `get` function, passing the map as the first argument and the key as the second.

In the following example, we extract the name of `wise-friend` using `(wise-friend :name)` and pass it to `print`, along with a second argument, `"is very wise."`:

```
(print (wise-friend :name)
       "is very wise.")
```

Output

```
Periyaar is very wise.nil
```

The output is `Periyaar is very wise.nil`. Try replacing `print` with `println` in the example above. What do you observe?

Since we used keywords as keys in `wise-friend`, we can also retrieve a value as shown:

```
(:name wise-friend)
```

Output

```
"Periyaar"
```

In the above code, we treat the keyword `:name` as a function and pass the map `wise-friend` to it to fetch the value.

Now, let's add a new key-value pair to `wise-friend`:

```
(assoc wise-friend :belief "Rationalism")
```

Output

```
{:name "Periyaar", :age 90, :belief "Rationalism"}
```

In the code above, we use the `assoc` (associate) function. We pass the map `wise-friend`, followed by the key `:belief` and the value `"Rationalism"`. In Clojure, data structures are immutable. The operation above returns a new map `{:name "Periyaar", :age 90, :belief "Rationalism"}`, and since we did not assign it to a variable, the result is not stored. You might think that `wise-friend` was modified to include the new key and value. However, if you query `wise-friend` for `:belief`, it will return `nil`:

```
(wise-friend :belief)
```

Output

```
nil
```

All original values in `wise-friend` remain intact. Let's query its age:

```
(wise-friend :age)
```

Output

```
90
```

Now, let's remove a key-value pair from `wise-friend` as shown:

```
(dissoc wise-friend :age)
```

Output

```
{:name "Periyaar"}
```

In the code above, we remove `:age` from `wise-friend`, resulting in a map containing only the `:name`. Once again, it is important to remember that Clojure did not change the original `wise-friend` map. The `dissoc` (disassociate) function takes `wise-friend` as the first argument and the key to be removed as the second, creating and returning a new map without that key. In Clojure, data structures are immutable.

If we query the keys of `wise-friend`, we still see both `:name` and `:age`, as shown:

```
(keys wise-friend)
```

Output

```
(:name :age)
```

To get the values stored in the map, pass it to the `vals` function, as shown:

```
(vals wise-friend)
```

Output

```
("Periyaar" 90)
```

`wise-friend` has the key `:name` (a keyword) and we can also use `"name"` (a string). This means you can have a map with both a keyword and a string as keys, even if they are spelled the same, as seen below:

```
(assoc wise-friend "name" "Ramasamy")
```

Output

```
{:name "Periyaar", :age 90, "name" "Ramasamy"}
```

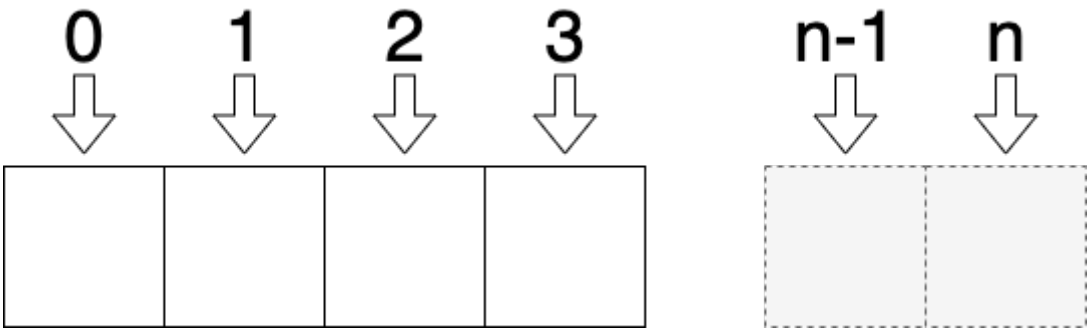
By adding `"name"` as a key and associating it with the value `"Ramasamy"`, we create a map with both `:name` and `"name"` as keys. Although this is possible, it is highly discouraged for the sake of code clarity.

4.5. Difference Between Vectors and Lists

Watch video for this section here https://yu7.in/clj-vec-list

If you had seen past few sections, you would have noticed vector is created by putting things between square brackets, and we can create a list by putting things between `'(` and `)`. Apart from that all operations are the same. So what's the real difference?

Imagine vector is a rack. Each compartment of the rack is named 0, 1, 2 and so on till n.



You can put anything in the compartment that's after the last filled one. See the example below:

```
(def numbers ["zero" "one" "two" "three" "four"])
(conj numbers "five")
```

Output

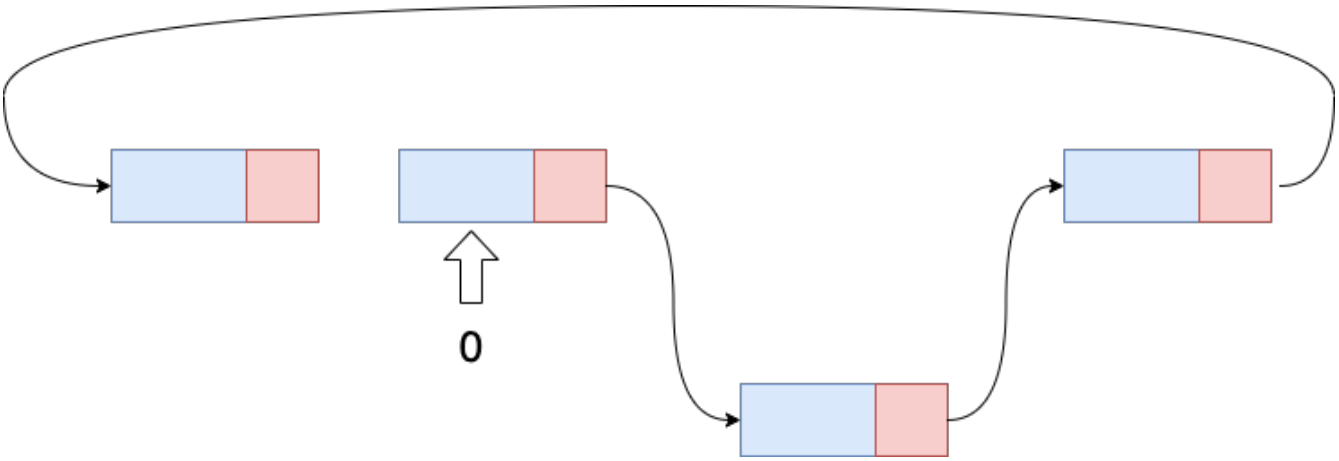
```
["zero" "one" "two" "three" "four" "five"]
```

In the above code, we add `"five"` to `numbers` and Clojure adds it to the last. A vector is a huge rack of contiguous spaces. Clojure can easily access any of the rack very easily because it's stored in a compact form in the memory. So even if you have a million element vector accessing the 7,546th is fast in Clojure. Like every thing this comes with a catch. Say you have a million element vector, and you want to add another element, if the adjacent space in memory is not available and is occupied by some other thing, Clojure should do the huge work finding continuous free space, then it must move all elements to it and add the new value at the end. This process of moving around data is very costly.

So if speed of random access with index is not important, and you need only sequential access, and if you want to add a lot of values to your collection, and you have large list to be stored, consider

list.

An element in a list has two parts. One is the value, and another one is a pointer to the next element. So elements of a list can be anywhere in your computer memory as shown below.



Adding a new element means it will have the value you push to it, and its pointer will point to current first element. So now the new value is the first element of the list. The drawback is, if you want to access the n^{th} element of a list, then Clojure needs to traverse through n - 1 elements to get to it. The positive is adding element is very easy.

[1] https://en.wikipedia.org/wiki/Random-access_memory

[2] https://en.wikipedia.org/wiki/Immutable_object

Chapter 5. Reading Clojure Documentation

Watch video for this section here https://yu7.in/clj-docs

You are reading this book because it documents Clojure. In programming, documentation is essential; almost all programming languages have a way of providing and accessing it. Clojure is no different. In this section, we will see how to access Clojure's documentation.

5.1. doc

Clojure has a function named `doc`. You pass any valid function name to it. For example, if we pass `+` to `doc`, its documentation is printed:

```
(doc +)
```

Output

```
clojure.core/+
([] [x] [x y] [x y & more])
  Returns the sum of nums. (+) returns 0. Does not auto-promote
  longs, will throw on overflow. See also: +'
nil
```

From the documentation above, we can see that `+` can receive no arguments and will return zero:

```
(+)
```

Output

```
0
```

This is confirmed by the output above. We can also infer that `+` accepts a single argument and returns that number:

```
(+ 42)
```

Output

```
42
```

This is also true. Finally, we can infer that `+` accepts two or more arguments and returns their sum, which is verified below:

```
(+ 40 2)
```

Output

```
42
```

```
(+ 10 30 2)
```

Output

```
42
```

5.2. find-doc

If you want to search the entire Clojure documentation text, you can use the `find-doc` function as shown below:

```
(find-doc "sum of nums")
```

Output

```
clojure.core/+
([] [x] [x y] [x y & more])
  Returns the sum of nums. (+) returns 0. Does not auto-promote
  longs, will throw on overflow. See also: +'
-------------------------
clojure.core/+'
([] [x] [x y] [x y & more])
  Returns the sum of nums. (+') returns 0. Supports arbitrary precision.
  See also: +
nil
clj□user□>
-------------------------
clojure.core/+
([] [x] [x y] [x y & more])
  Returns the sum of nums. (+) returns 0. Does not auto-promote
  longs, will throw on overflow. See also: +'
-------------------------
clojure.core/+'
([] [x] [x y] [x y & more])
  Returns the sum of nums. (+') returns 0. Supports arbitrary precision.
  See also: +
```

Above I have found functions whose documentation contains the string "sum of nums".

5.3. apropos

If you want to search for functions whose names contain a specific string, use the `apropos` function as shown below:

```
(apropos "replace")
```

Output

```
(clojure.core/replace clojure.string/re-quote-replacement clojure.string/replace
clojure.string/replace-first clojure.walk/postwalk-replace clojure.walk/prewalk-
replace clojure.zip/replace)
```

Above, I used the `apropos` function to find all functions whose names contain the string `"replace"`. Now, let's check the documentation of the `replace` function to see what it does:

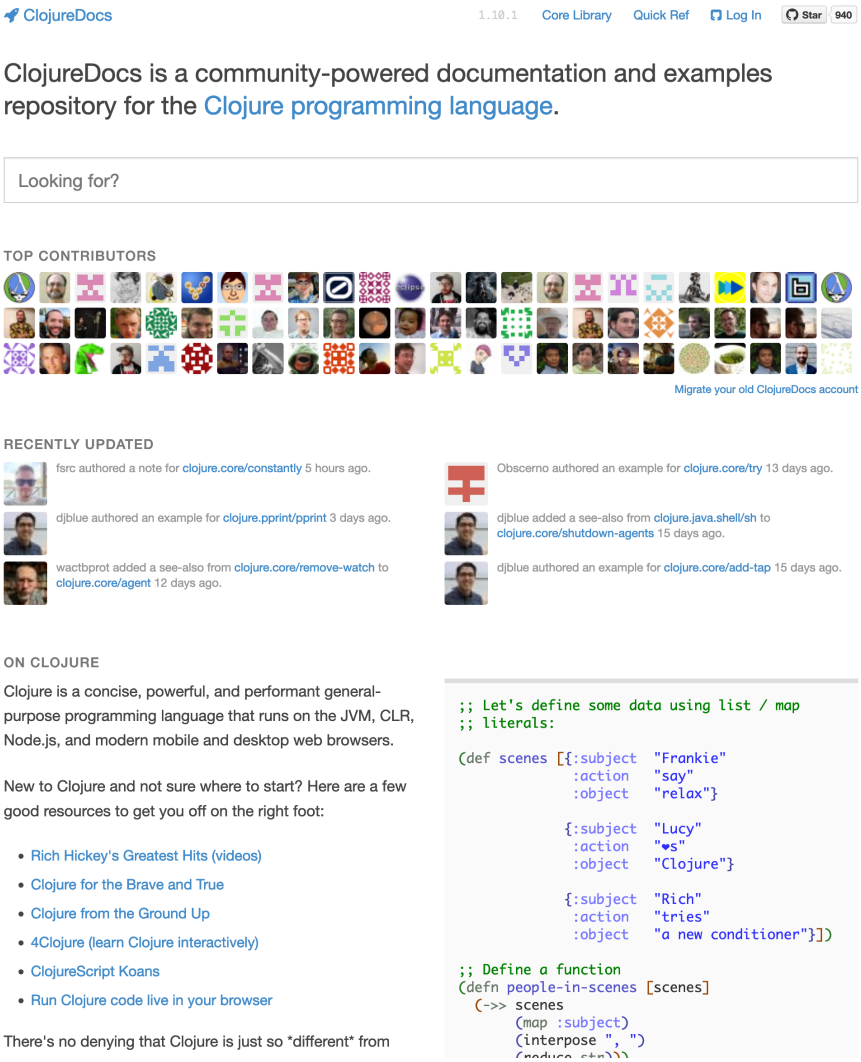
```
(doc replace)
```

Output

```
-------------------------
clojure.core/replace
([smap] [smap coll])
  Given a map of replacement pairs and a vector/collection, returns a
  vector/seq with any elements = a key in smap replaced with the
  corresponding val in smap.  Returns a transducer when no collection
  is provided.
nil
```

5.4. Clojure docs online

If you are not comfortable using the Clojure REPL to access documentation, you can use Clojure's online documentation available at https://clojuredocs.org/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1.10.1
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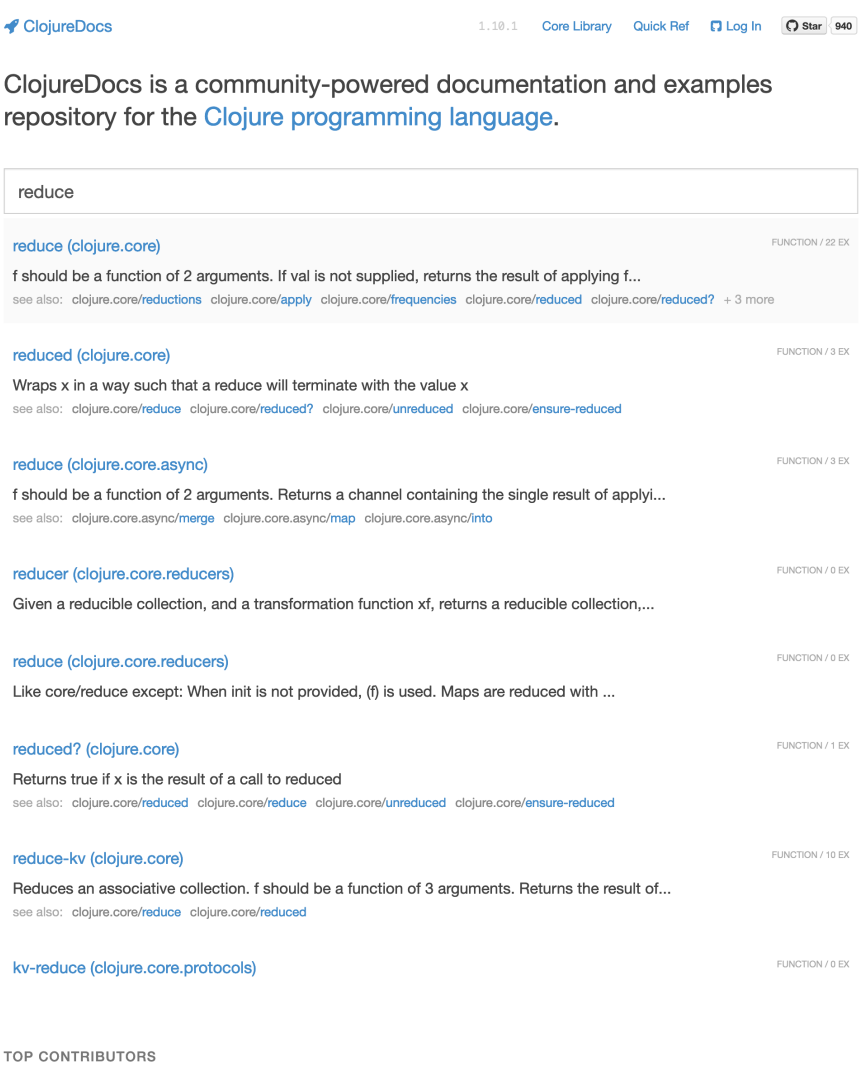
ClojureDocs is a community-powered documentation and examples repository for the Clojure programming language.
Looking for?
TOP CONTRIBUTORS
Migrate your old ClojureDocs account
RECENTLY UPDATED
fsrc authored a note for clojure.core/constantly 5 hours ago.
djblue authored an example for clojure.pprint/pprint 3 days ago.
wactbprot added a see-also from clojure.core/remove-watch to clojure.core/agent 12 days ago.
Obscerno authored an example for clojure.core/try 13 days ago.
djblue added a see-also from clojure.java.shell/sh to clojure.core/shutdown-agents 15 days ago.
djblue authored an example for clojure.core/add-tap 15 days ago.
ON CLOJURE
Clojure is a concise, powerful, and performant general-purpose programming language that runs on the JVM, CLR, Node.js, and modern mobile and desktop web browsers.
New to Clojure and not sure where to start? Here are a few good resources to get you off on the right foot:
Rich Hickey's Greatest Hits (videos)
Clojure for the Brave and True
Clojure from the Ground Up
4Clojure (learn Clojure interactively)
ClojureScript Koans
Run Clojure code live in your browser
There's no denying that Clojure is just so *different* from
;; Let's define some data using list / map
;; literals:
(def scenes [{:subject "Frankie"
:action "say"
:object "relax"}
{:subject "Lucy"
:action "♥s"
:object "Clojure"}
{:subject "Rich"
:action "tries"
:object "a new conditioner"}])
;; Define a function
(defn people-in-scenes [scenes]
(->> scenes
(map :subject)
(interpose ", ")

In the image below, searching for `reduce` shows all functions whose names contain the word "reduce".


ClojureDocs
1.10.1
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940
ClojureDocs is a community-powered documentation and examples repository for the Clojure programming language.
reduce
reduce (clojure.core)
FUNCTION / 22 EX
f should be a function of 2 arguments. If val is not supplied, returns the result of applying f...
see also: clojure.core/reductions clojure.core/apply clojure.core/frequencies clojure.core/reduced clojure.core/reduced? + 3 more
reduced (clojure.core)
FUNCTION / 3 EX
Wraps x in a way such that a reduce will terminate with the value x
see also: clojure.core/reduce clojure.core/reduced? clojure.core/unreduced clojure.core/ensure-reduced
reduce (clojure.core.async)
FUNCTION / 3 EX
f should be a function of 2 arguments. Returns a channel containing the single result of applyi...
see also: clojure.core.async/merge clojure.core.async/map clojure.core.async/into
reducer (clojure.core.reducers)
FUNCTION / 0 EX
Given a reducible collection, and a transformation function xf, returns a reducible collection,...
reduce (clojure.core.reducers)
FUNCTION / 0 EX
Like core/reduce except: When init is not provided, (f) is used. Maps are reduced with ...
reduced? (clojure.core)
FUNCTION / 1 EX
Returns true if x is the result of a call to reduced
see also: clojure.core/reduced clojure.core/reduce clojure.core/unreduced clojure.core/ensure-reduced
reduce-kv (clojure.core)
FUNCTION / 10 EX
Reduces an associative collection. f should be a function of 3 arguments. Returns the result of...
see also: clojure.core/reduce clojure.core/reduced
kv-reduce (clojure.core.protocols)
FUNCTION / 0 EX
TOP CONTRIBUTORS

Clicking on `reduce` displays its documentation:

ClojureDocs is a convenient way to access documentation in a browser.

Chapter 6. Logic and comparison

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/logic_and_comparison.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Watch video for this section here https://yu7.in/clj-logic-comp

Clojure comes with functions that help us compare values. For example, you can use the equals `=` function to check if two things are equal, as shown below:

```
(= 1 1)
```

Output

```
true
```

Since 1 is equal to 1, the above code returns `true`. In the code below, 1 is not equal to 2, and hence `=` returns `false` when `1` and `2` are passed as arguments to it:

```
(= 1 2)
```

Output

```
false
```

`=` does not just compare two arguments; you can pass any number of arguments to it, and it returns `true` only when all arguments are equal.

```
(= 7 7 7 )
```

Output

```
true
```

```
(= 7 8 7)
```

Output

```
false
```

The greater than `>` function is used to check if the first argument passed to it is greater than the second one:

```
(> 1 2)
```

Output

```
false
```

```
(> 2 1)
```

Output

```
true
```

If you provide it with more than two arguments, it will check if the arguments are passed in descending order; if so, it will return `true`:

```
(> 3 2 1)
```

Output

```
true
```

The greater than or equal to `>=` function returns `true` if the arguments passed to it are either greater than or equal to the second one. In the code below, 5 is equal to 5, and hence it will return `true`:

```
(>= 5 5)
```

Output

```
true
```

In the example below, 6 is greater than 5, and hence it's `true`:

```
(>= 6 5)
```

Output

```
true
```

The code below returns `false` because 6 is neither greater than 7 nor equal to 7:

```
(>= 6 7)
```

Output

```
false
```

The less than function `<` returns `true` if the arguments passed to it are in ascending order. Below, 1 is less than 2, so `true` is returned:

```
(< 1 2)
```

Output

```
true
```

In the example below, 1 is less than 2, which is less than 3, and hence `true` is returned:

```
(< 1 2 3)
```

Output

```
true
```

2 is not less than 1, and hence the code below returns `false`:

```
(< 2 1)
```

Output

```
false
```

The code below returns `false` because 1, 3, and 2 are not passed to `<` in ascending order:

```
(< 1 3 2)
```

Output

```
false
```

The code below returns `true` because 7 is equal to 7:

```
(<= 7 7)
```

Output

```
true
```

The code below returns `true` because 7 is less than or equal to 8:

```
(<= 7 8)
```

Output

```
true
```

The code below returns `false` because 8 is neither less than 7 nor equal to it:

```
(<= 8 7)
```

Output

```
false
```

Now let's look at logical functions. The `and` function returns `true` if all the arguments passed to it are `true`:

```
(and true true)
```

Output

```
true
```

If any of the arguments passed to `and` are `false`, it returns `false`.

```
(and true false)
```

Output

```
false
```

The `or` function returns `true` if any of the arguments passed to it are `true`:

```
(or true true)
```

Output

```
true
```

```
(or true false)
```

Output

```
true
```

```
(or false false)
```

Output

```
false
```

The `not` function simply inverts `true` to `false` and vice versa:

```
(not true)
```

Output

```
false
```

```
(not false)
```

Output

```
true
```

Chapter 7. Conditions and branching

In programming, the flow of execution often needs to change based on the data or information available. For example, while anyone can visit the landing page of a website, a user attempting to access a secured page must be presented with a login screen if they are not already logged in. In such cases, we must check specific conditions and branch the program flow accordingly.

In this section, we will explore how to implement this in Clojure.

7.1. if

Watch video for this section here https://yu7.in/clj-if

`if` is one of the basic condition checking functions in Clojure. Let's try out a simple example. Execute the code shown below:

```
;; if.clj

(let [a 5]
  (if (> a 0)
    (println a "is positive")))
```

Output

```
5 is positive
nil
```

We get the result `5 is positive` as shown above. So we get the following, to an `if` the first argument is condition check, over here its `(> a 0)`, if the condition check returns `true`, then the second argument passed `(println a "is positive")` is executed.

Now modify the program as shown:

```
;; if.clj

(let [a -5]
  (if (> a 0)
    (println a "is positive")))
```

Output

```
nil
```

In the above code, `a` is `-5` and hence `(> a 0)` fails. In theory then the third argument passed to `if`

should execute, we have first argument `(> a 0)`, and second argument `(println a "is positive")`, there is no third argument, so `nil` gets returned.

Now let's give a third argument to it, see the code below and execute it:

```
;; if_else.clj

(let [a -5]
  (if (> a 0)
    (println a "is positive")
    (println a "is negative")))
```

Output

```
-5 is negative
nil
```

In the above code `a` is `-5` and hence `(> a 0)` fails. In then the third argument should execute. In this case, the third argument is `(println a "is negative")` gets executed and `-5 is negative` gets printed out.

Take a look at the code below, execute it.

```
;; if_nested.clj

(let [a 5]
  (if (> a 0)
    (println a "is positive")
    (if (< a 0)
      (println a "is negative")
      (println a "is neither positive nor negative"))))
```

Output

```
5 is positive
nil
```

So in the above code `(> a 0)` is `true`, so the first argument passed to it `(println a "is positive")` is executed and above output is printed.

Now let's change `a` to `-5` and see what happens.

```
;; if_nested.clj

(let [a -5]
  (if (> a 0)
```

```
    (println a "is positive")
    (if (< a 0)
      (println a "is negative")
      (println a "is neither positive nor negative"))))
```

Output

```
-5 is negative
nil
```

So the second argument passed to `if` is:

```
(if (< a 0)
      (println a "is negative")
      (println a "is neither positive nor negative"))
```

This argument itself contains a `if`, let's call it nested if, and here the condition passed to it `(< a 0)` passes, so the second argument passed to the nested if `(println a "is negative")` gets executed and `-5 is negative` gets printed out.

Now what if `a` is zero, once again it comes to the second argument to the top level `if`, which is

```
(if (< a 0)
      (println a "is negative")
      (println a "is neither positive nor negative"))
```

In the code above `(< a 0)` fails, and the third argument passed to nested `if (println a "is neither positive nor negative")` gets executed, and we have execution as shown below:

```
;; if_nested.clj

(let [a 0]
  (if (> a 0)
    (println a "is positive")
    (if (< a 0)
      (println a "is negative")
      (println a "is neither positive nor negative"))))
```

Output

```
0 is neither positive nor negative
nil
```

`if` function can accept only 3 arguments, the first one is a condition, the second argument will get

executed when the condition passes, the third will get executed when condition fails. So what if we want to execute more than one statement if a condition passes or fails, well, wrap them in `do` as shown:

```
;; if_multiple_statements_in_branch.clj

(let [a 5]
  (if (> a 0)

    (do
      (println a "is positive")
      (println "There are infinite positive numbers"))

    (do
      (println a "is negative")
      (println "There are infinite negative numbers"))))
```

Output

```
5 is positive
There are infinite positive numbers
nil
```

Now let's make `a` negative and execute it:

```
;; if_multiple_statements_in_branch.clj

(let [a -5]
  (if (> a 0)

    (do
      (println a "is positive")
      (println "There are infinite positive numbers"))

    (do
      (println a "is negative")
      (println "There are infinite negative numbers"))))
```

Output

```
-5 is negative
There are infinite negative numbers
nil
```

7.2. when

Watch video for this section here https://yu7.in/clj-when

`if` accepts a condition as first argument, as second it accepts what should be done if the condition is `true`, and third is what should be done if the condition is `false`. `if` does work when the third argument is left out, but if we want to execute a bunch of statements when a condition is `true`, then we can use `when` as shown below:

```
;; when.clj

(let [print-something true]
  (when print-something
    (println "I print something.")
    (println "I print other things too.")))
```

Output

```
I print something.
I print other things too.
nil
```

Type the above program and execute it. When `print-something` is `true`, then the statements:

```
(println "I print something.")
(println "I print other things too.")
```

in the form

```
(when print-something
    (println "I print something.")
    (println "I print other things too."))
```

get's executed, and we get the output shown above.

Now let's set `print-something` to `false` as shown below and execute the code:

```
;; when.clj

(let [print-something false]
  (when print-something
    (println "I print something.")
    (println "I print other things too.")))
```

Output

```
nil
```

Nothing gets printed. So if the first argument passed to `when` is `true`, all statements enclosed in its form gets executed, else nothing happens.

7.3. cond

What if you want to check multiple conditions and execute different code based on which one is met? Welcome to `cond` (short for conditional). Take a look at the example below and try executing it:

```
;; cond.clj

(let [number 5]
  (cond
    (> number 0) (println number "is positive.")
    (< number 0) (println number "is negative.")
    :else (println number "is neither positive nor negative.")))
```

Output

```
5 is positive.
nil
```

It prints `5 is positive` because we set `number` to `5` using the `let` binding. The `cond` form is structured as follows:

```
(cond
    (> number 0) (println number "is positive.")
    (< number 0) (println number "is negative.")
    :else (println number "is neither positive nor negative."))
```

In this code, since `number` is greater than `0`, the condition `(> number 0)` is satisfied, and the associated expression `(println number "is positive.")` is executed.

Try changing `number` to a negative value, execute the code, and observe the result. If no preceding conditions are satisfied, the `:else` clause is executed:

```
:else (println number "is neither positive nor negative.")
```

Set `number` to `0` and execute the code to see the result.

Now, try executing the following code and analyze its behavior:

```
(let [number 5]
  (cond
    (> number 0) (println number "is positive.")
    (< number 0) (println number "is negative.")))
```

Set `number` to `0`, execute it, and observe what happens.

7.4. case

Watch video for this section here https://yu7.in/clj-case

Below is an example of `case`, type it and execute it.

```
;; case.clj

(let [num 20]
  (case num
    1 "one"
    2 "two"
    3 "three"
    4 "four"
    5 "five"
    "I don't know"))
```

Output

```
"I don't know"
```

We get `"I don't know"`, so what happens? We have set `num` to `20` in `let [num 20]`, then we pass `num` to `case` as shown:

```
(case num
  ........)
```

So `case` checks the value of `num`. Since `num` is not `1`, the statement `1 "one"` is not touched.

```
(case num
    1 "one"
    ........)
```

Similarly, `num` is not `2`, `3`, `4`, or `5`, so all the statements below are not touched.

```
(case num
```

```
1 "one"
2 "two"
3 "three"
4 "four"
5 "five"
........)
```

Finally, the default case `"I don't know"` is executed as shown below:

```
(case num
    ........
    "I don't know")
```

And it gets returned.

As an exercise, remove the `"I don't know"` and run the code. What do you get? Change `num` to `4` and run the code. What do you get? How can you explain it?

When `num` is `4`, and `"I don't know"` is removed, does it matter? Why?

When `num` is `20`, and `"I don't know"` is removed, does it matter? Why?

Chapter 8. Loops

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/loops.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Watch video for this section here https://yu7.in/clj-loops

In programming, when you need to repeat an action, you use loops. In this section, we will explore them.

Clojure handles repetition differently than imperative languages. While it doesn't have traditional 'for' or 'while' loops in the same sense, it provides powerful alternatives. This section explores those alternatives.

8.1. for

The first construct we'll look at is `for`. Type and execute the following code:

```
(let [nums [1 2 3 4]]
  (for [num nums]
       (* num 10)))
```

Output

```
(10 20 30 40)
```

Let's see how it works. The expression

```
(let [nums [1 2 3 4]])
```

binds `[1 2 3 4]` to the symbol `nums`. Then we use `for` as follows:

```
(let [nums [1 2 3 4]]
  (for [num nums]
    ;; loop body
       ))
```

In the expression `(for [num nums] ⋯)`, the `[num nums]` part defines the binding. The body will be executed four times. On the first iteration, the first value in `nums`, `1`, is bound to `num`; on the second iteration, `2` is bound to `num`, and so on.

In the body, we multiply `num` by 10. Let's put `(* num 10)` in the loop body as shown:

```
(let [nums [1 2 3 4]]
  (for [num nums]
       (* num 10)))
```

Here is how `for` works: on the first iteration, `num` is `1` and the body returns 10. `for` collects this into a sequence. On the next iteration, `num` is 2 and the body returns 20, which is added to the sequence. This continues until all elements are processed, and `for` returns the final sequence: `(10 20 30 40)`.

Now let's use `for` with multiple sequences. Type and execute the following program:

```
(def colors ["red" "blue" "green" "yellow"])

(def shapes ["square" "circle" "triangle" "rectangle"])

(for [color colors
      shape shapes]
  (str color " " shape))
```

Output

```
("red square" "red circle" "red triangle" "red rectangle" "blue square" "blue circle"
"blue triangle" "blue rectangle" "green square" "green circle" "green triangle" "green
rectangle" "yellow square" "yellow circle" "yellow triangle" "yellow rectangle")
```

In this expression:

```
(def colors ["red" "blue" "green" "yellow"])
```

we define a vector of four colors called `colors`. Similarly, in this expression:

```
(def shapes ["square" "circle" "triangle" "rectangle"])
```

we define a vector of four shapes called `shapes`. Now we can use `for` to combine every color with every shape. Look at this:

```
(for [color colors]
  ;; loop body
  )
```

In the code above, `for` iterates through each item in `colors`. During the first iteration, `color` is bound to `"red"`, and during the last, it is bound to `"yellow"`.

To combine these with `shapes`, we add another binding for `shape`:

```
(for [color colors
      shape shapes]
  ;; loop body
  )
```

It executes as follows: first, `"red"` is bound to `color` and `"square"` to `shape`. Then the body executes, concatenating them with `str`. Here is the complete code:

```
(for [color colors
      shape shapes]
  (str color " " shape))
```

In the first iteration, `"red"`, a space, and `"square"` are concatenated, and `for` collects `"red square"`. Then, `shape` takes the next value, `"circle"`, resulting in `"red circle"`. This process continues for all shapes before `color` moves to the next value, `"blue"`. Ultimately, `for` returns the following sequence:

```
("red square" "red circle" "red triangle" "red rectangle" "blue square" "blue circle"
"blue triangle" "blue rectangle" "green square" "green circle" "green triangle" "green
rectangle" "yellow square" "yellow circle" "yellow triangle" "yellow rectangle")
```

8.2. doseq

`doseq` is similar to `for` in its iteration syntax, but it is designed for side effects and always returns `nil`. Look at the code below. Unlike `for`, it will not return a sequence of results. Use `doseq` when you want to perform an action without returning a value.

`doseq` is used for repetitive actions that produce side effects, such as printing to the console, writing to a file, sending emails, or updating a database.

```
(let [nums [1 2 3 4]]
  (doseq [num nums]
    (* num 10)))
```

Output

```
nil
```

Although `doseq` returns `nil`, you can perform actions within the loop body. For example, we can print the result of the multiplication:

```
(let [nums [1 2 3 4]]
  (doseq [num nums]
```

```
    (println (* num 10))))
```

Output

```
10
20
30
40
nil
```

In a real-world scenario, this could be used to send emails to a list of recipients where no return value is needed.

8.3. loop

Finally, let's look at `loop`. Type and execute the following program:

```
(loop [x 1]
  (when (<= x 5)
    (println x)
    (recur (inc x))))
```

Output

```
1
2
3
4
5
nil
```

Here is how it works. First, we define the `loop` construct:

```
(loop )
```

Now, we initialize a binding `x` to `1`:

```
(loop [x 1])
```

To print numbers from 1 to 5, we need a condition to stop the loop. We use `when` to check if `x` is less than or equal to 5:

```
(loop [x 1]
```

```
  (when (<= x 5)
    ))
```

The first part of `loop` is the binding `[x 1]`, followed by the body containing the condition check:

```
(when (<= x 5)
    )
```

Whenever `x` is less than or equal to 5, the body of the `when` expression is executed.

Now we add a call to `println` to print the current value of `x`:

```
(loop [x 1]
  (when (<= x 5)
    (println x)))
```

To continue the loop, we use `recur` to jump back to the start of the `loop` with an updated value for `x`. We pass `(recur (inc x))` as the final expression in the `when` block:

```
(loop [x 1]
  (when (<= x 5)
    (println x)
    (recur (inc x))))
```

Now the `loop` starts again, but this time `x` is 2. Since `(<= x 5)` is still true, 2 is printed. This continues until `x` becomes 6, at which point `(<= x 5)` fails, and the loop terminates.

8.4. dotimes

Watch video for this section here https://yu7.in/clj-dotimes

If you know in advance how many times an action needs to be repeated, you can use `dotimes`. Let's look at an example.

We start with `dotimes`:

```
(dotimes )
```

We pass a vector containing the counter and the number of iterations:

```
(dotimes [])
```

To repeat an action five times, we specify `5`:

```
(dotimes [5])
```

To use the current iteration count, we bind it to a variable, such as `x`:

```
(dotimes [x 5])
```

Now we print the value of `x`:

```
(dotimes [x 5]
  (println x))
```

Running the code above produces the following result:

```
0
1
2
3
4
```

In most programming languages, counting starts at 0. This is why the output begins with 0. There are five distinct numbers from 0 to 4, meaning the body was executed five times.

Here is another example:

```
(dotimes [_ 5]
  (println "Hello World!"))
```

Running this code produces the following output:

```
Hello World!
Hello World!
Hello World!
Hello World!
Hello World!
```

As you can see, `"Hello World!"` is printed five times. You might wonder why we used an underscore `_` instead of a variable like `x`. By convention, an underscore is used when the iteration counter is not needed in the body of the loop.

Chapter 9. Functions

Watch video for this section here https://yu7.in/clj-st-fun

Abstraction is the key to greatness and progress. Michael Faraday discovered a link between electricity and magnetism, but I don't think about it when I drive my car. Everything is abstracted away behind the steering wheel and pedals. Abstraction is so important that almost every programming language provides a way to abstract away complexity.

Functions are the way you can abstract away things in Clojure. Whenever code becomes complex, you can refactor it into functions and use those functions as building blocks. In fact, you have been using functions all along; for example, when you call `(+ 1 2)` in Clojure, `+` is a function, and `1` and `2` are the values it receives. Technically, we call the values received by a function arguments. You don't know what happens in the computer when you execute `( 1 2)`; it's been neatly abstracted away behind the function `+`.

So let's see how to build our own functions in this chapter.

9.1. Saying Hello With Functions

Here is the code in Clojure to print Hello World:

```
(println "Hello world!")
```

Now, let's make this functionality available by calling `(say-hello)`. To do that, we use `defn` (short for define function):

```
(defn )
```

First, we pass the function name `say-hello` as an argument:

```
(defn say-hello)
```

Now that `say-hello` is passed to `defn`, we need to specify the arguments. Since we don't need any arguments to print 'Hello World!', we use empty square brackets `[]` to indicate that no arguments are accepted.

```
(defn say-hello [])
```

Now, we write the function body. In this case, we simply print 'Hello World!', as shown below:

```
(defn say-hello []
  (println "Hello world!"))
```

Whenever we call `(say-hello)`, 'Hello World!' is printed. The code below shows the final version of `say-hello`:

```
;; function_say_hello.clj

(defn say-hello []
  (println "Hello world!"))

(say-hello)
```

Output

```
Hello world!
nil
```

9.2. Passing Arguments

We can pass arguments to functions. For example, consider a function $f(x) = x^2 + 2$. This function accepts an argument x; if we plug in 7 for x, we get $f(7) = 51$. Similarly, a function in Clojure can take an argument and perform an operation with it.

Look at the say hello example below, type it, and execute it:

```
;; function_with_arguments.clj

(defn say-hello [name]
  (println "Hello" name "!"))

(say-hello "Karthik")
```

Output

```
Hello Karthik !
nil
```

It prints `Hello Karthik !`. But how does it work? By writing `(defn say-hello ⋯)`, we define a function named `say-hello`. Notice the `[name]` part shown below:

```
(defn say-hello [name]
  ;; function body goes here
  )
```

The `name` is an argument that must be passed for the function to run. It can be used as a variable within the function body. Notice the structure of the function: it starts with `defn`, followed by the

function name `say-hello`, and then the square brackets containing the argument name `[name]`. Now let's finish off the function by writing its body as shown:

```
(defn say-hello [name]
  (println "Hello" name "!"))
```

In the function body, we are printing a greeting to the `name`. We pass `name` to `println` as follows: `(println "Hello" name "!")`.

Calling `say-hello` with the argument `"Karthik"`: `(say-hello "Karthik")` prints `Hello Karthik !`. Modify the program to say hello to you.

9.2.1. Finding Area Of Circle

The area of a circle is calculated as πr^2. Given that the radius of a circle is stored in a variable `radius`, we can write Clojure code to find the area as shown below:

```
(* Math/PI (Math/pow radius 2))
```

Instead of writing the calculation every time, it would be better to find the area by calling a function named `circle-area`. This is how we implement it in the code below:

```
;; function_circle_area.clj

(defn circle-area [radius]
  (* Math/PI (Math/pow radius 2)))

(circle-area 7)
```

Output

```
153.93804002589985
```

In the above code, rather than dealing with `Math/PI` and calculating the power each time, all we need to do is call `(circle-area 7)`, and we get the area of a circle with a radius of 7 units. A well-designed function abstracts away complexity and allows us to write better programs.

9.3. Refactoring

Imagine a friend is building a billion-dollar startup with an app that helps customers calculate the area of a circle. After a successful pitch and investment round, your friend claimed that thousands of people want to calculate the area of a circle every day and that his app would be incredibly useful. He knows you are a great programmer, so you coded the `circle-area` function for him. The app is released, and humanity is saved.

You realize that instead of calculating the area using `(* Math/PI (Math/pow radius 2))`, you can simply use `(* Math/PI radius radius)`. The latter is much simpler and easier to maintain. Consequently, all you need to do is change the code in one place, as shown below:

```
;; function_circle_area_refactored.clj

(defn circle-area [radius]
  (* Math/PI radius radius))

(circle-area 7)
```

The rest of the app's code is completely unaware of this change and continues to work perfectly. If you hadn't abstracted the logic into a function and had instead placed `(* Math/PI (Math/pow radius 2))` in 50 different places throughout the app, making such a change and testing it would have been incredibly difficult.

Thus, functions lead to better code and reduce the likelihood of bugs.

9.4. Functions with Multiple Arguments

Watch video for this section here https://yu7.in/clj-mul-arg

Functions aren't limited to a single argument. For example, if you want to calculate the hypotenuse of a right-angled triangle with sides of lengths a and b, it can be represented as a function $f(a, b) = \sqrt{a^2 + b^2}$. Now let's code this in Clojure:

```
;; hypotenuse.clj

(defn hypotenuse [a b]
  (Math/sqrt (+ (* a a) (* b b))))

(hypotenuse 3 4)
```

Output

```
5.0
```

In the code above, we define a function `hypotenuse` that takes two arguments, `a` and `b`. It should now be clear that if a function takes no arguments, the function name is followed by empty square brackets `[]`; if it does take arguments, their names are included within those brackets, such as `[a b]`. In the function body, we use `(Math/sqrt (+ (* a a) (* b b)))` to compute and return the hypotenuse.

When we call `(hypotenuse 3 4)`, `5.0` gets returned.

Suppose you need a function that can accept either one or two arguments. Clojure allows this

through function overloading. Look at the code below:

```
;; function_multiple_arguments.clj

(defn multiple-args
  ([arg-1] (println "One argument passed:" arg-1))
  ([arg-1 arg-2] (println "Two arguments passed:" arg-1 arg-2)))

(multiple-args 1)
(multiple-args 1 2)
```

Output

```
One argument passed: 1
Two arguments passed: 1 2
```

We have a function called `multiple-args`, defined as follows:

```
(defn multiple-args
  ;; function body goes here
  )
```

To allow the function to accept a single argument, we add a form as shown below:

```
(defn multiple-args
  ([arg-1] (println "One argument passed:" arg-1)))
```

This form:

```
([arg-1] (println "One argument passed:" arg-1))
```

receives one argument, `arg-1`:

```
([arg-1] ...)
```

In the function body, we print the argument using `(println "One argument passed:" arg-1)`:

```
([arg-1] (println "One argument passed:" arg-1))
```

So this will respond to a function call like `(multiple-args 1)`.

To support two arguments, we add another form with two parameters:

```
([arg-1 arg-2] (println "Two arguments passed:" arg-1 arg-2))
```

This is our complete function definition, which can accept either one or two arguments:

```
(defn multiple-args
  ([arg-1] (println "One argument passed:" arg-1))
  ([arg-1 arg-2] (println "Two arguments passed:" arg-1 arg-2)))
```

`([arg-1 arg-2] (println "Two arguments passed:" arg-1 arg-2))` is executed when we call `(multiple-args 1 2)`.

As an exercise, try writing code that allows you to call `(multiple-args)`, which should print 'No argument passed'. If you find this difficult, refer to `function_multiple_arguments_exercise.clj` in the code examples.

9.5. Accepting Unlimited Arguments

Clojure functions can accept an unlimited number of arguments. For example, the `+` function can accept any number of arguments and return their sum:

```
(+ 1 2 3 5 7 -1)
```

Output

```
17
```

For a function to accept an unlimited number of arguments, prefix the last argument in the argument vector with the `&` symbol. Take a look at the code below:

```
;; function_unlimited_arguments.clj

(defn unlimited-arguments [& args]
  (println "Arguments:" args)
  (println "Type of args:" (type args)))

(unlimited-arguments 1)
(println)
(unlimited-arguments 1 17 true "Karthik" :coder)
```

Output

```
Arguments: (1)
Type of args: clojure.lang.ArraySeq
```

```
Arguments: (1 17 true Karthik :coder)
Type of args: clojure.lang.ArraySeq
```

In this example, `& args` in the argument vector allows the `unlimited-arguments` function to accept any number of arguments.

For example, if we call the function like this:

```
(unlimited-arguments 1)
```

We get the output `Arguments: (1)`, which is generated by this statement:

```
(println "Arguments:" args)
```

In the previous snippet, we simply printed the arguments. In the next snippet:

```
(println "Type of args:" (type args))
```

We print the type of `args`, which is `clojure.lang.ArraySeq` (a type of sequence). Similarly, when we call:

```
(unlimited-arguments 1 17 true "Karthik" :coder)
```

All arguments— `1`, `17`, `true`, `"Karthik"`, and `:coder`—are bundled into `args` as a sequence, as seen in the output: `Arguments: (1 17 true Karthik :coder)`.

To define a function that accepts one or more arguments, you can write it like this:

```
;; function_unlimited_arguments_2.clj

(defn unlimited-arguments [first-arg & args]
  (println "First argument:" first-arg)
  (println "Other arguments:" args))

(unlimited-arguments 1)
(println)
(unlimited-arguments 1 17 true "Karthik" :coder)
```

Output

```
First argument: 1
Other arguments: nil
```

```
First argument: 1
Other arguments: (17 true Karthik :coder)
```

In the argument vector `[first-arg & args]`, the first argument is captured by `first-arg`, and any subsequent arguments are bundled into `args`.

In the following example, the `unlimited-arguments` function requires a minimum of two arguments:

```
;; function_unlimited_arguments_3.clj

(defn unlimited-arguments [first-arg second-arg & args]
  (println "First argument:" first-arg)
  (println "Second argument:" second-arg)
  (println "Other arguments:" args))

(unlimited-arguments 1 2)
(println)
(unlimited-arguments 1 17 true "Karthik" :coder)
```

Output

```
First argument: 1
Second argument: 2
Other arguments: nil

First argument: 1
Second argument: 17
Other arguments: (true Karthik :coder)
```

The first argument is captured by `first-arg`, the second by `second-arg`, and any additional arguments are bundled as a sequence in `args`.

9.6. Returning Values

Watch video for this section here https://yu7.in/clj-ret

Consider a mathematical function, such as $f(x) = x^2 + 2$. If you plug in a value, say $x = 7$, the function returns 51. Similarly, you expect a programming function to return a value.

In Clojure, the result of the last expression executed by a function is its return value. Take, for example, the code below:

```
;; function_returning_something.clj

(defn add [a b]
  (+ a b))
```

```
(println (add 2  3))
```

Output

```
5
nil
```

In the code above, the result of `(+ a b)` is returned from the `add` function. Since `(+ a b)` is the last expression in the `add` function, its result is returned, captured by `println`, and then printed. You might have noticed `nil` in the output. This is because `println`, after printing `5`, returns `nil`, which is then printed by the REPL.

Another clear example is any built-in math function in Clojure, such as `+`:

```
(+ 1 2 3 4 5)
```

This returns `15`. If you try this in the REPL, you will see `15` rather than `nil` because the expression evaluates to a value. In Clojure, `nil` represents the absence of a value or 'nothingness'.

Let's write a function to see how the return value is determined. Try executing the following example:

```
;; what_it_returns.clj

(defn do-math [a b]
  (+ a b)
  (* a b))

(do-math 5 3)
```

Output

```
15
```

In the `do-math` function, the first expression is `(+ a b)`. When `(do-math 5 3)` is called, `(+ a b)` evaluates to `8`, but this result is discarded. The last expression is `(* a b)`, which returns `15`; this is the final return value of `do-math` and the value that appears in the output.

Now, let's define another function by swapping the `*` and `+` operators, as shown below:

```
;; what_it_returns_2.clj

(defn do-math [a b]
  (* a b)
```

```
  (+ a b))

(do-math 5 3)
```

Output

```
8
```

In the code above, since `(+ a b)` is the last expression, its result is returned, and the result of `(* a b)` is discarded.

The key takeaway is that the result of the last expression in a function is what gets returned.

9.7. Recursion

Watch video for this section here https://yu7.in/clj-recursion

A function calling itself is known as recursion. For example, look at the code below:

```
;; function_recursion.clj

(defn count-down [number]
  (println number)
  (if (pos? (dec number))
    (count-down (dec number))))

(count-down 5)
```

Output

```
5
4
3
2
1
nil
```

When this function is executed, it prints numbers from 5 down to 1 and then stops. We called the function like this: `(count-down 5)`. Let's analyze the function body:

```
(println number)
(if (pos? (dec number))
  (count-down (dec number)))
```

First, the expression `(println number)` prints `5`, and then the execution moves to the following form:

```
(if (pos? (dec number))
  (count-down (dec number)))
```

In the code above, `(dec number)` evaluates to `4`. Since `4` is positive, `(pos? 4)` is `true`, and the expression `(count-down (dec number))` is executed, resulting in a call to `(count-down 4)`. That is, the function `count-down` calls itself.

This process continues until `number` becomes `0`. At that point, `(dec number)` is `-1`, making `(pos? -1)` `false`. Consequently, `(count-down (dec number))` is not executed, and the recursion terminates.

You can perform recursion by calling the function by name, as seen in the previous example, or by using the `recur` special form, as shown below:

```
;; function_recur.clj

(defn count-down [number]
  (println number)
  (if (pos?  (dec number))
    (recur (dec number))))

(count-down 5)
```

Output

```
5
4
3
2
1
nil
```

In the example above, we replaced the function name `count-down` with `recur` when the function calls itself. Using `recur` is more memory-efficient because it performs tail-call optimization. For `recur` to work, it must be the last expression executed in the function.

In the following example, we use recursion to compute the sum of a sequence of numbers. Try executing the code below, and we will analyze its execution shortly.

```
;; function_sum_using_recursion.clj

(defn sum [numbers total]
  (if (empty? numbers)
    total
    (recur (rest numbers) (+ total (first numbers)))))
```

```
(println (sum [1 2 3 4 5] 0))
```

Output

```
15
nil
```

In the previous example, we called `(sum [1 2 3 4 5] 0)`, which returned `15`. To simplify the analysis, let's use a smaller example:

```
(sum [1 2] 0)
```

So, what happens when the above code is executed? Let's look at the body of `sum`:

```
(if (empty? numbers)
  total
  (recur (rest numbers) (+ total (first numbers))))
```

`(empty? [1 2])` evaluates to `false`, so the following expression is executed:

```
(recur (rest numbers) (+ total (first numbers)))
```

Substituting the values, we get:

```
(recur (rest [1 2]) (+ 0 (first [1 2])))
```

This can be reduced to:

```
(recur [2] (+ 0 1))
```

Which simplifies to:

```
(recur [2] 1)
```

Since `recur` calls the current function, we can represent this as:

```
(sum [2] 1)
```

Now, `sum` is called with `numbers` as `[2]` and `total` as `1`. Since `(empty? [2])` is again `false`, we reach the following expression:

```
(recur (rest numbers) (+ total (first numbers)))
```

Substituting the values, we get:

```
(recur (rest [2]) (+ 1 (first [2])))
```

Reducing the expression, we get:

```
(recur [] (+ 1 2))
```

Replacing `recur` with `sum` and simplifying `(+ 1 2)` to `3`, we get:

```
(sum [] 3)
```

Now `numbers` is `[]` and `total` is `3`. Let's plug these into the function:

```
(if (empty? numbers)
  total
  (recur (rest numbers) (+ total (first numbers))))
```

Here, `(empty? numbers)` is `true`, so `total` is returned. Thus, `3` is returned, which is the sum of the vector `[1 2]`.

What if you want a function that takes only a sequence and computes its sum without requiring an initial total? See the example below:

```
;; function_collection_sum.clj

(defn sum [numbers total]
  (if (empty? numbers)
    total
    (recur (rest numbers) (+ total (first numbers)))))

(defn collection-sum [collection]
  (sum collection 0))

(println (collection-sum [1 2 3 4 5]))
```

Output

```
15
nil
```

In this example, the `collection-sum` function takes a collection. It abstracts the process by passing the collection and an initial `total` of `0` to the previously defined `sum` function, which uses recursion to calculate the total.

9.8. Multimethods

Watch video for this section here https://yu7.in/clj-mm and here https://yu7.in/clj-mmm

Suppose you pass arguments to a function, and based on the values passed, Clojure determines which specific method should be called. This technique is known as multimethods.

Examine the code below, then type and execute it:

```
;; multimethod_factorial.clj

(defmulti factorial identity)

(defmethod factorial 0 [_]  1)

(defmethod factorial :default [num]
  (* num (factorial (dec num))))

(factorial 0) ; => 1
(factorial 1) ; => 1
(factorial 3) ; => 6
(factorial 7) ; => 5040
```

In the line `(defmulti factorial identity)`, we declare a multimethod called `factorial`. The dispatch value (which determines the execution path) is defined by the `identity` function. Now, we define the behavior for when the identity is `0`:

```
(defmethod factorial 0)
```

Next, we specify the arguments:

```
(defmethod factorial 0 [_])
```

Since we aren't using the argument, we follow the convention of using an underscore `_`. We then specify that the function should return `1`:

```
(defmethod factorial 0 [_] 1)
```

For any other dispatch value, we use the `:default` keyword:

```
(defmethod factorial :default)
```

We define the argument as `num`:

```
(defmethod factorial :default [num])
```

We return $n \cdot (n-1)!$ as shown below:

```
(defmethod factorial :default [num]
  (* num (factorial (dec num))))
```

This results in clean and elegant code for calculating the factorial of any number.

Now consider the code below:

```
;; without_multimethods.clj

(defn print-welcome-message [person]
  (cond
    (string? person) (println "Welcome" person)
    (vector? person) (println  "Welcome" (first person) "from" (last person))
    (map? person)    (println "Welcome" (person "name") "from" (person "from"))))

(print-welcome-message "Karthik from Chennai")
(print-welcome-message ["Kalam" "Ramanthapuram"])
(print-welcome-message {"name" "Bharathiyaar" "from" "Yettaiyapuram"})
```

Output

```
Welcome Karthik from Chennai
Welcome Kalam from Ramanthapuram
Welcome Bharathiyaar from Yettaiyapuram
```

The `print-welcome-message` function accepts `person` as an argument. Depending on whether `person` is a string, a vector, or a map, the program extracts the data and prints it, as shown in the following block:

```
 (cond
    (string? person) (println "Welcome" person)
    (vector? person) (println  "Welcome" (first person) "from" (last person))
    (map? person)    (println "Welcome" (person "name") "from" (person "from")))
```

The same functionality can be implemented using multimethods, as shown in the code below. Type and execute it, and I will explain the process:

```
;; with_multimethods.clj

(defn welcome-person [person]
  (cond
    (string? person) :welcome-person-string
    (vector? person) :welcome-person-vector
    (map? person)    :welcome-person-map))

(defmulti print-welcome-message welcome-person)

(defmethod print-welcome-message :welcome-person-string [person]
  (println "Welcome" person))

(defmethod print-welcome-message :welcome-person-vector [person]
  (println  "Welcome" (first person) "from" (last person)))

(defmethod print-welcome-message :welcome-person-map [person]
  (println "Welcome" (person "name") "from" (person "from")))

(print-welcome-message "Karthik from Chennai")
(print-welcome-message ["Kalam" "Ramanthapuram"])
(print-welcome-message {"name" "Bharathiyaar" "from" "Yettaiyapuram"})
```

Output

```
Welcome Karthik from Chennai
Welcome Kalam from Ramanthapuram
Welcome Bharathiyaar from Yettaiyapuram
```

First you have a multimethod definition:

```
(defmulti print-welcome-message welcome-person)
```

This statement defines the multimethod `print-welcome-message` and specifies that the `welcome-person` function will determine which method to execute.

Now let's see what's there in `welcome-person`:

```
(defn welcome-person [person]
  (cond
    (string? person) :welcome-person-string
    (vector? person) :welcome-person-vector
    (map? person)    :welcome-person-map))
```

The `welcome-person` function accepts `person` as an argument and returns a keyword that identifies the appropriate execution path.

Now let's look at the definition of methods:

```
(defmethod print-welcome-message :welcome-person-string [person]
  (println "Welcome" person))

(defmethod print-welcome-message :welcome-person-vector [person]
  (println  "Welcome" (first person) "from" (last person)))

(defmethod print-welcome-message :welcome-person-map [person]
  (println "Welcome" (person "name") "from" (person "from")))
```

Let's look at the first one:

```
(defmethod print-welcome-message :welcome-person-string [person]
  (println "Welcome" person))
```

In `welcome-person`, if `person` is a string, the function returns `:welcome-person-string`. The corresponding method is defined above, starting with `defmethod`:

```
(defmethod)
```

Followed by the multimethod name:

```
(defmethod print-welcome-message)
```

Next, we provide the keyword determined by `welcome-person`. In this case, if `person` is a string, this specific code is executed:

```
(defmethod print-welcome-message :welcome-person-string)
```

This is followed by the argument `person`:

```
(defmethod print-welcome-message :welcome-person-string [person])
```

Finally, we provide the function body, `(println "Welcome" person)`:

```
(defmethod print-welcome-message :welcome-person-string [person]
  (println "Welcome" person))
```

Depending on the data type, `welcome-person` returns different keywords, triggering the execution of the corresponding `defmethod`. This allows us to isolate different execution paths into separate methods, keeping the code simple and manageable.

9.9. Pre and Post Condition Checking

Watch video for this section here https://yu7.in/clj-prepo

Most functions require data to operate on. If the data is not provided in the correct format, the function may fail. It is a good practice to validate the arguments passed to a function. Clojure provides a `:pre` hook for this purpose. Let's see how it works using an example. Type the code below:

```
;; function_pre.clj

(defn sum [a b]
  {:pre [(number? a) (number? b)]}
  (+ a b))

(println (sum 4 5))
;; (println (sum "4" 5)) ;; Throws an error
```

Executing `(println (sum 4 5))` works as expected, but `(println (sum "4" 5))` throws an error. This is because of the following code snippet in `sum`:

```
{:pre [(number? a) (number? b)]}
```

This is a map with a `:pre` key. Since we may want to check multiple conditions, we pass them as a vector. In this case, we check if the first argument `a` is a number using `(number? a)` and if the second argument `b` is a number using `(number? b)`. The function body is executed only if all conditions in the vector are true.

For `(sum 4 5)`, both `a` and `b` are numbers, so the `sum` function executes. For `(sum "4" 5)`, `"4"` is a string, causing `(number? a)` to be false and triggering an error.

If you need to verify that the returned value has a specific format or structure, you can use a `:post` hook, as shown below:

```
;; function_post.clj

(defn sum [a b]
  {:post [(number? %)]}
  "45")

(defn sum-without-post [a b]
  "45")

(println (sum-without-post 4 5))
(println (sum 4 5)) ;; ; Assert failed: (number? %)
```

Execute the code above. In this example, both `sum` and `sum-without-post` return the string `"45"`. Executing `(sum-without-post 4 5)` runs without issues. However, since the sum of two numbers should be a number, `(sum 4 5)` throws an error because it returns a string, which violates the `:post` hook:

```
{:post [(number? %)]}
```

The `:post` hook expects the return value (represented by the `%` symbol) to be a number.

Now let's see `pre` and `post` hooks in action:

```
;; function_pre_post.clj

(defn sum [a b]
  {:pre [(number? a) (number? b)]
   :post [(number? %)]}
  (+ a b))

(println (sum 4 5))
```

What do you think will happen if we call `(sum 4 "5")` using the code above?

9.10. Docstrings

Watch video for this section here https://yu7.in/clj-docstr

Documentation is crucial in programming. Clojure provides a built-in way to document functions, which are first-class citizens in the language. Examine the code below:

```
;; docstring.clj

(defn sum
  "Adds two numbers passed as arguments.

   The arguments should be numbers.

   **Usage**

   ```clojure
   (sum 4 5) ;; returns 9
   ```
  "
  [a b]
  {:pre [(number? a) (number? b)]}
  (+ a b))
```

```
(println (sum 4 5))
```

Immediately after `(defn sum`, we provide a docstring:

```
"Adds two numbers passed as arguments.

  The arguments should be numbers.

  **Usage**

  ```clojure
  (sum 4 5) ;; returns 9
  ```
"
```

This string serves as the documentation for the function. Note the use of **Usage**, which follows Markdown formatting. I've also included a code block within the docstring:

```
```clojure
(sum 4 5) ;; returns 9
```
```

This instructs the documentation viewer to highlight `(sum 4 5)

returns 9` as Clojure code.

You can access the documentation for `sum` using the `doc` function, as shown below:

```
clj□user□> (doc sum)
-------------------------
user/sum
([a b])
  Adds two numbers passed as arguments.

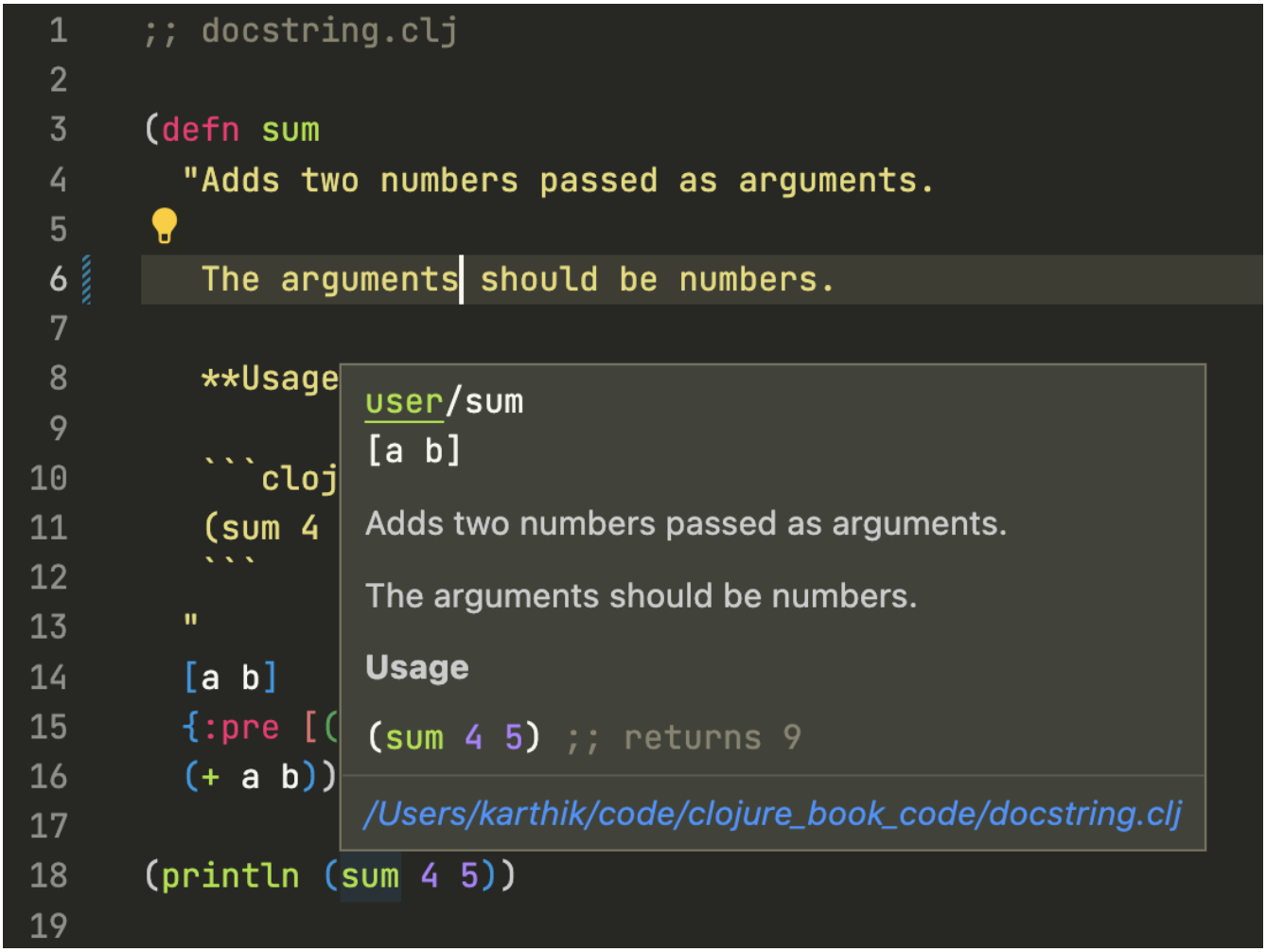
   The arguments should be numbers.

   **Usage**

   ```clojure
   (sum 4 5) ;; returns 9
   ```

nil
```

Alternatively, in VSCodium, you can simply hover over the function name to see the documentation in a neat popup, as shown here:



9.11. Anonymous Functions

Watch video for this section here https://yu7.in/clj-frf

You can define functions without assigning them a name; these are known as anonymous functions. Try the code below:

```
;; anonymous_function.clj

(def print-something
  (fn [something]
    (println something)))

(print-something "something is better than nothing")
```

Output

```
something is better than nothing
```

Look at this snippet:

```
(fn [something]
  (println something))
```

This expression returns a function that accepts a single argument called `something`. When this function is called with a value, it prints that value. Notice that the function returned in the snippet above has no name; it exists as a functional entity, but it lacks a symbolic identifier.

You can assign a name to an anonymous function by binding it to a symbol, as shown below:

```
(def print-something
  (fn [something]
    (println something)))
```

In the snippet above, the anonymous function is bound to the symbol `print-something`. You can now call it using that name: `(print-something "something is better than nothing")`.

In fact, `defn` is essentially a shortcut that combines the definition of a function with `fn` and its assignment to a name via `def`.

Specifically, writing this:

```
(def print-something
  (fn [something]
    (println something)))
```

is equivalent to writing it like this:

```
(defn print-something [something]
    (println something))
```

and it will work the same way.

9.12. Functions Returning Functions

Watch video for this section here https://yu7.in/clj-frf

You might be wondering what the use of anonymous functions is? Take a look at the example below and execute it:

```
;; function_returning_function.clj

(defn multiplier [multiply-with]
  (fn [number]
    (* number multiply-with)))
```

```
(def double-it
  (multiplier 2))

(def triple-it
  (multiplier 3))

(double-it 21)

(triple-it 14)
```

When `(double-it 21)` is executed, it returns `42`. Now, let's look at the definition of `double-it`:

```
(def double-it
  (multiplier 2))
```

In the code above, `double-it` is assigned the output of `(multiplier 2)`. Since `double-it` behaves as a function, `(multiplier 2)` must return a function. Let's examine the source of `multiplier`:

```
(defn multiplier [multiply-with]
  (fn [number]
    (* number multiply-with)))
```

Now take a look at what `multiplier` returns:

```
(fn [number]
  (* number multiply-with))
```

As shown above, it returns a function. If we replace `multiply-with` with `2`, we get the following:

```
(fn [number]
  (* number 2))
```

The resulting code is a function that takes a `number` and returns its product with `2`. Now, substitute this into the definition of `double-it`:

```
(def double-it
  (multiplier 2))
```

we get the following:

```
(def double-it
  (fn [number]
```

```
    (* number 2)))
```

In short, we could have written it as:

```
(defn double-it [number]
    (* number 2))
```

In the `multiplier` function, we are essentially constructing new functions and returning them, which we then name. This is a powerful concept known as higher-order functions.

Chapter 10. Debugging With Calva

For this section you can use this code https://gitlab.com/clojure-book/code/-/raw/master/executing_form.clj

Large codebases are often built by composing many small code snippets. To ensure these snippets behave as expected, you need a way to execute and evaluate them incrementally.

Calva is a Clojure plugin for VS Code that allows you to execute code and evaluate expressions. It also provides powerful debugging tools. In this section, we will learn how to use Calva to evaluate and debug Clojure code.

10.1. Connecting to a REPL

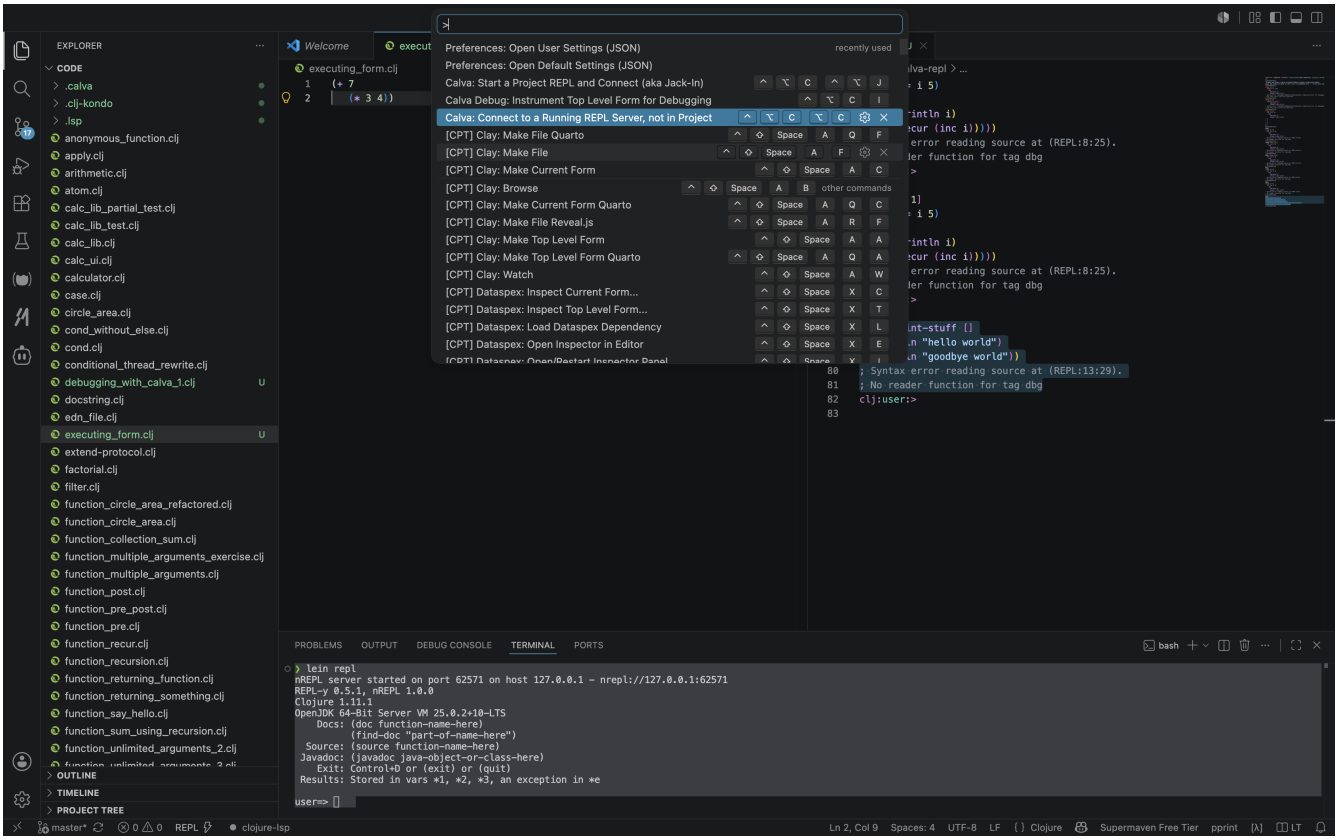
In VS Code, launch your terminal and type `lein repl`. You should see something like this:

```
$ lein repl
nREPL server started on port 62571 on host 127.0.0.1 - nrepl://127.0.0.1:62571
REPL-y 0.5.1, nREPL 1.0.0
Clojure 1.11.1
OpenJDK 64-Bit Server VM 25.0.2+10-LTS
    Docs: (doc function-name-here)
          (find-doc "part-of-name-here")
  Source: (source function-name-here)
 Javadoc: (javadoc java-object-or-class-here)
    Exit: Control+D or (exit) or (quit)
 Results: Stored in vars *1, *2, *3, an exception in *e

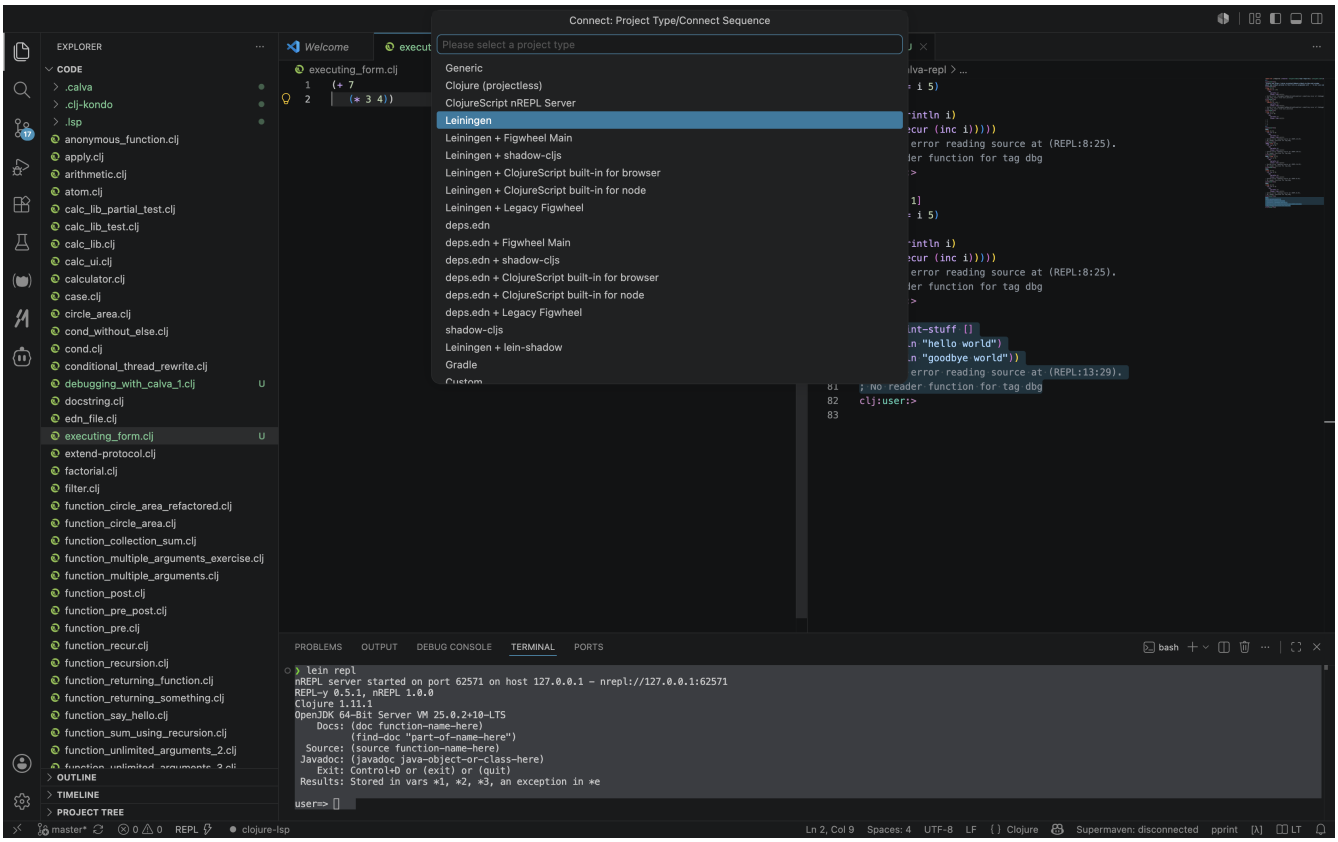
user=>
```

Note the `nrepl://127.0.0.1:62571`, where `127.0.0.1` is the host and `62571` is the port. We will use this information to connect to the REPL.

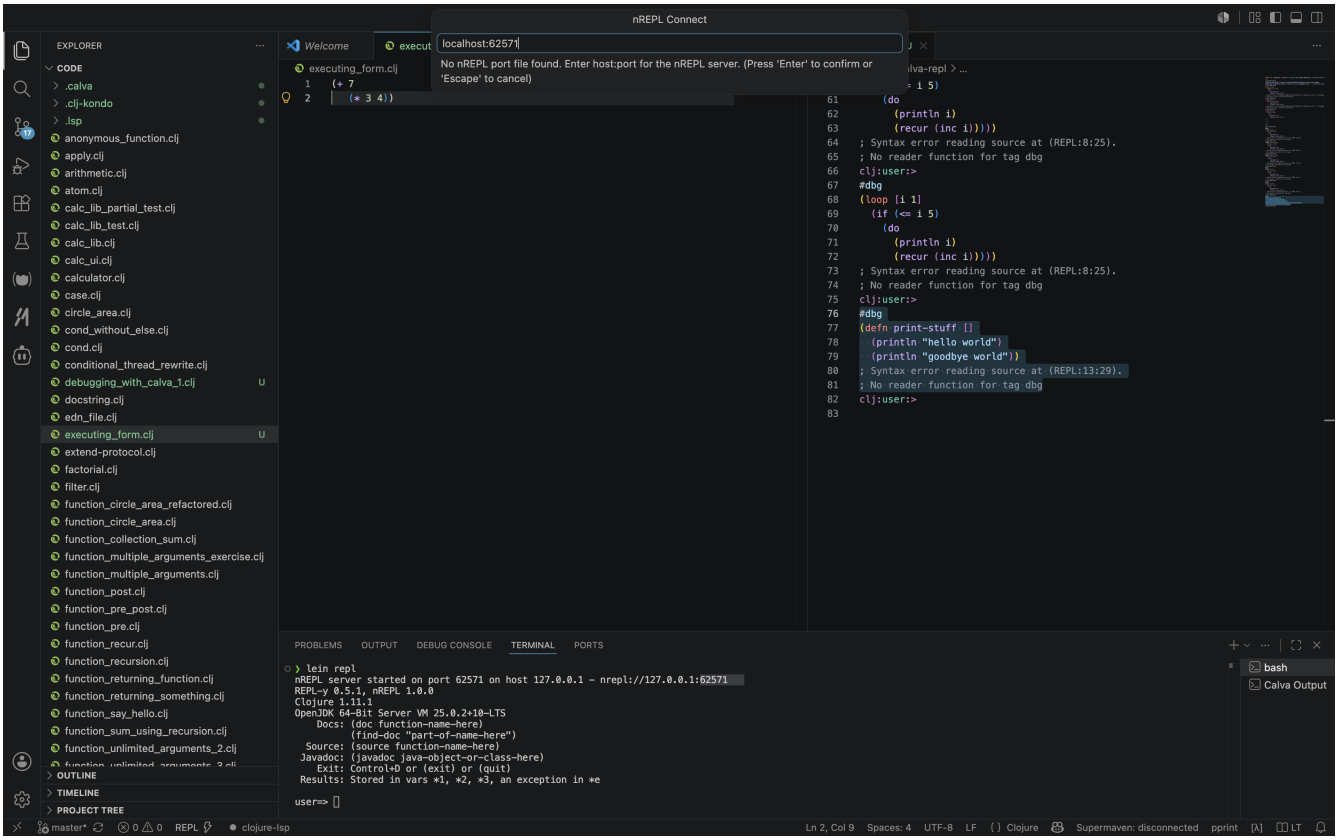
Open the command palette `command` + `shift` + `p` on MacOS or `ctrl` + `shift` + `p` on Linux/Windows and type `Calva: Connect to Running REPL Server, not in Project`. You should see something like this:


Preferences: Open User Settings (JSON)
Preferences: Open Default Settings (JSON)
Calva: Start a Project REPL and Connect (aka Jack-In)
Calva Debug: Instrument Top Level Form for Debugging
Calva: Connect to a Running REPL Server, not in Project
[CPT] Clay: Make File Quarto
[CPT] Clay: Make File
[CPT] Clay: Make Current Form
[CPT] Clay: Browse
[CPT] Clay: Make Current Form Quarto
[CPT] Clay: Make File Reveal.js
[CPT] Clay: Make Top Level Form
[CPT] Clay: Make Top Level Form Quarto
[CPT] Clay: Watch
[CPT] Dataspex: Inspect Current Form...
[CPT] Dataspex: Inspect Top Level Form...
[CPT] Dataspex: Load Dataspex Dependency
[CPT] Dataspex: Open Inspector in Editor
PROBLEMS
OUTPUT
DEBUG CONSOLE
TERMINAL
PORTS
nREPL server started on port 62571 on host 127.0.0.1 - nrepl://127.0.0.1:62571
REPL-y 0.5.1, nREPL 1.0.0
Clojure 1.11.1
OpenJDK 64-Bit Server VM 25.0.2+10-LTS
user=>

Once you have selected that option, you should see something like this:



Select Leiningen. You should see something like this:



After `localhost:`, enter the port number you noted down. It may be different from the one shown here; in this example, it is `62571`.

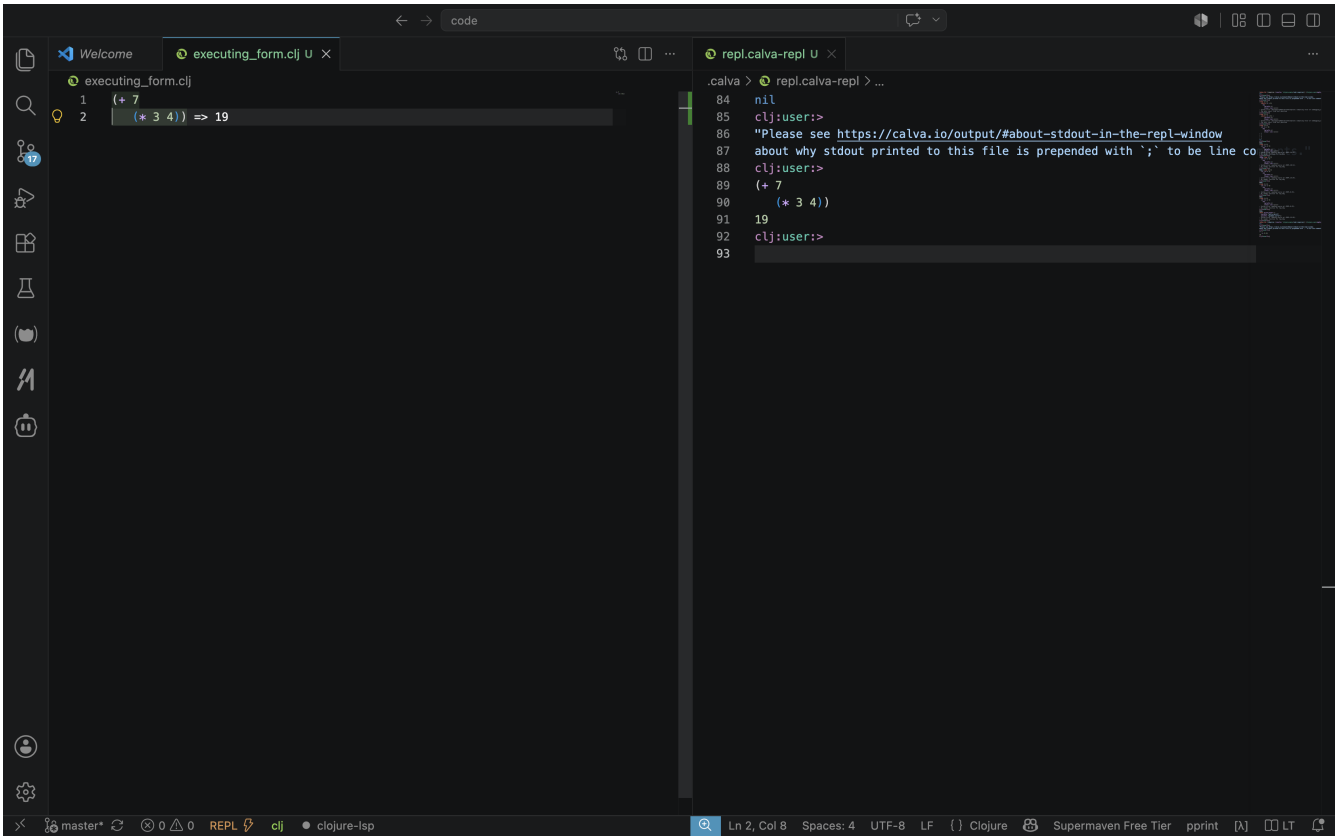
Once that's done, you should be connected to the REPL.

10.2. Executing Top Level Form

Let's create a simple file called `executing_form.clj` and add the following code to it:

```
(+ 7
  (* 3 4))
```

Now place the cursor anywhere within `(+ 7 (* 3 4))` and press `alt`+`enter` on GNU/Linux or `option`+`enter` on macOS. You should see something like this:


code
Welcome
executing_form.clj U
executing_form.clj
1 (+ 7
2 (* 3 4)) => 19
repl.calva-repl U
.calva > repl.calva-repl > ...
84 nil
85 clj:user:>
86 "Please see https://calva.io/output/#about-stdout-in-the-repl-window
87 about why stdout printed to this file is prepended with `;` to be line co
88 clj:user:>
89 (+ 7
90 (* 3 4))
91 19
92 clj:user:>
93
master* 0 0 REPL clj clojure-lsp
Ln 2, Col 8 Spaces: 4 UTF-8 LF { } Clojure Supermaven Free Tier pprint LT

On the right, in the REPL, the result is 19. It is very convenient to evaluate code and see the results immediately in the REPL.

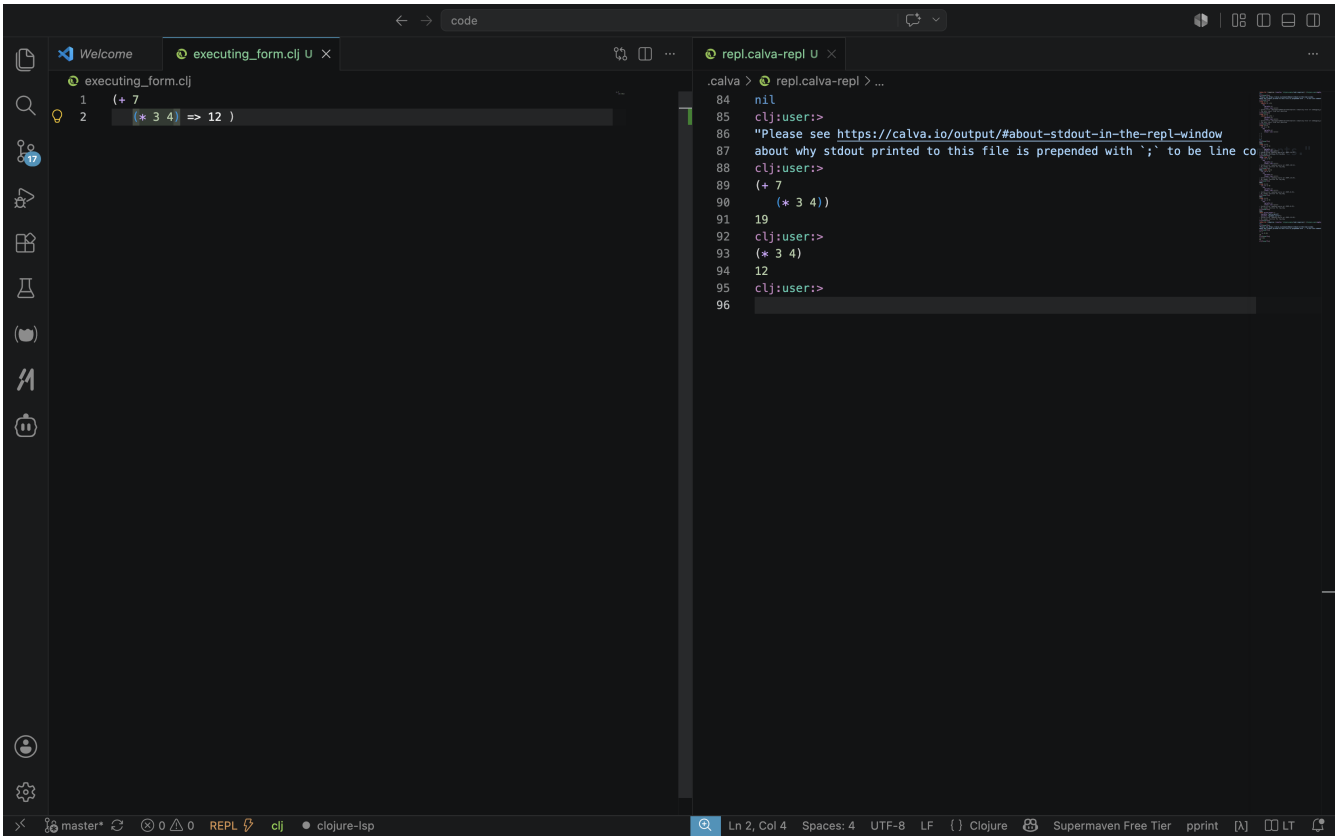
10.3. Executing Current Form

The code we have in `executing_form.clj` is:

```
(+ 7
  (* 3 4))
```

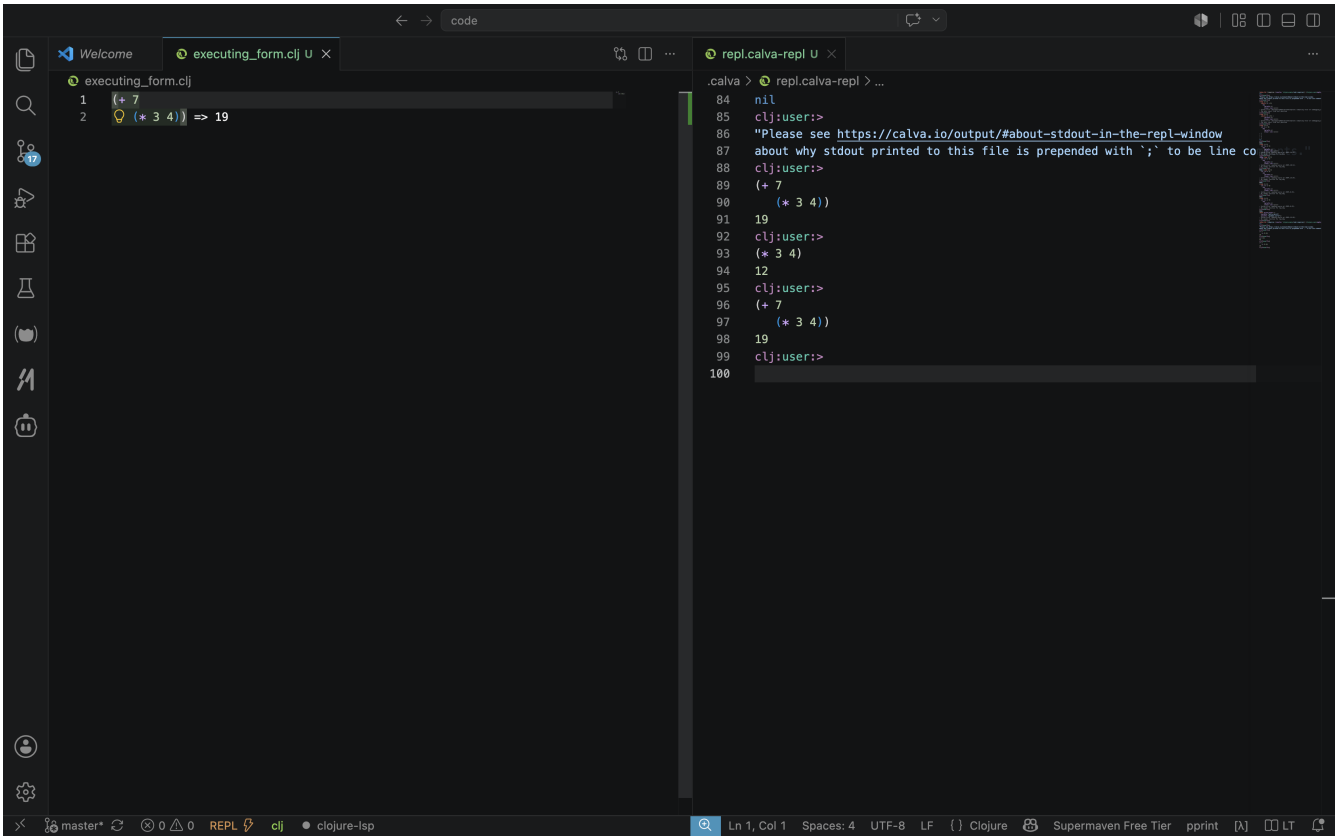
There are two forms here: the top-level form is `(+ 7 (* 3 4))`, and the inner form is `(* 3 4)`.

Place the cursor anywhere before the starting paranthesis of `(* 3 4)` and press `ctrl`+`enter` on GNU/Linux and macOS. You should see something like this:



Notice that the result is 12. This is because the cursor was just before the form `(* 3 4)`, and `ctrl + enter` executes the current form.

Now let's execute the top-level form. Place the cursor just before the outermost bracket of `(+ 7 (* 3 4))` and press `ctrl`+`enter` on GNU/Linux or macOS. You should see something like this:



Notice that the result is 19. This is because the cursor was just outside the form `(+ 7 (* 3 4))`, and

`ctrl`+`enter` executes the current form, which in this case is the entire top-level form.

The key takeaway from this section is that `ctrl`+`enter` executes the current form.

Chapter 11. Spec

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/spec.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Watch video for this section here https://yu7.in/clj-spec

Clojure programs consist of functions that manipulate data. Data can be of any type, such as Strings, Numbers, Maps, Vectors, and Sets. When data of the incorrect type or format is provided to a function, the function may not behave as expected. To prevent this, Clojure provides built-in libraries to verify data types and formats, known as **specs**. You can use specs to verify that received data is correct (pre-conditions) or that returned data conforms to the expected format (post-conditions).

To use specs, let's first require the library:

```
(require '[clojure.spec.alpha :as s])
```

We have required `clojure.spec.alpha` as `s`, so we can call its functions using the `s/` prefix (e.g., `s/valid?` instead of `spec.alpha/valid?`).

Let's see how to check if a value is a string:

```
(s/valid? string? "Hello")
```

Output

```
true
```

In the example above, we use `s/valid?` and pass it the predicate function `string?`. The `string?` function returns `true` if its argument is a string. Since `"Hello"` is a string, `s/valid?` returns `true`.

If we check if the number 42 is a string:

```
(s/valid? string? 42)
```

Output

```
false
```

Since `(string? 42)` returns `false`, `(s/valid? string? 42)` also returns `false`, failing the validation.

Similarly, we can check if a value is a number:

```
(s/valid? number? 42)
```

Output

```
true
```

Since 42 is a number, `(number? 42)` returns `true` and thus `(s/valid? number? 42)` returns `true`.

We can also check if a value is an integer:

```
(s/valid? integer? 123)
```

Output

```
true
```

Or if it is a double (a number with a decimal point):

```
(s/valid? double? 123.45)
```

Output

```
true
```

Since 123 does not have a decimal point, the check for a double fails:

```
(s/valid? double? 123)
```

Output

```
false
```

We can also verify collections. For instance, checking if `[1 2 3]` is a vector:

```
(s/valid? vector? [1 2 3])
```

Output

```
true
```

Checking if a value is a map:

```
(s/valid? map? { 1 "one" 2 "two"})
```

Output

```
true
```

Checking for a set:

```
(s/valid? set? #{:apple :orange})
```

Output

```
true
```

Checking for a keyword:

```
(s/valid? keyword? :ubuntu)
```

Output

```
true
```

Now let's consider a more complex scenario: validating a percentage for a grading system. A valid percentage must be a number between 0 and 100 (inclusive). We can define a spec for this using `s/and`:

```
(def valid-%? (s/and number? #(>= % 0) #(<= % 100)))
```

Output

```
#'user/valid-%?
```

To build this spec, we need the value to be a number:

```
number?
```

And it must be greater than or equal to zero. We use `s/and` to combine these requirements:

```
(s/and
  number?
  #(>= % 0))
```

Finally, it must be less than or equal to 100. We add one more predicate to the `s/and` form:

```
(s/and
  number?
  #(>= % 0)
  #(<= % 100))
```

We assign this spec to the name `valid-%?`:

```
(def valid-%?
  (s/and
    number?
    #(>= % 0)
    #(<= % 100)))
```

For brevity, you can define it on a single line:

```
(def valid-%? (s/and number? #(>= % 0) #(<= % 100)))
```

Now let's test our `valid-%?` spec:

```
(s/valid? valid-%? 85)
```

Output

```
true
```

Because 85 is a number between 0 and 100, it is valid. However, 105% is invalid in this grading system:

```
(s/valid? valid-%? 105)
```

Output

```
false
```

Similarly, -15 is less than 0, so it also returns `false`:

```
(s/valid? valid-%? -15)
```

Output

```
false
```

Exercise

Write a spec named `string-or-keyword?` that works as follows:

```
(s/valid? string-or-keyword? "abc") ;; true
(s/valid? string-or-keyword? :abc) ;; true
(s/valid? string-or-keyword? 42) ;; false
```

For this exercise, you may want to look at https://clojuredocs.org/clojure.spec.alpha/or

11.1. Specing Collections

Watch video for this section here https://yu7.in/clj-spec-col

Let's see how to spec collections. In the example below, we define `string-collection?`:

```
(def string-collection? (s/coll-of string?))
```

Output

```
#'user/string-collection?
```

The `s/coll-of` spec checks if every element in a collection conforms to the provided spec (in this case, `string?`). Let's apply `string-collection?` to a vector of strings:

```
(s/valid? string-collection? ["Hi" "Hello"])
```

Output

```
true
```

It passes because both `"Hi"` and `"Hello"` are strings. Note that we pass the spec `string-collection?` as the first argument to `s/valid?`, and the vector `["Hi" "Hello"]` as the second.

Now let's handle a more complex case: a collection that can contain either numbers or strings.

```
(def number-or-string? (s/or :number number? :string string?))
```

Output

```
#'user/number-or-string?
```

In the code above, we use `s/or`. We provide pairs of tags (keywords) and specs: `:number number?` and `:string string?`. These tags are useful for reporting which part of the `or` spec matched or failed during explanation. The `s/or` spec passes if the value matches **any** of the provided specs.

Testing it with a number:

```
(s/valid? number-or-string? 1)
```

Output

```
true
```

Testing it with a string:

```
(s/valid? number-or-string? "Hi")
```

Output

```
true
```

To check if a collection contains only numbers or strings, we wrap `number-or-string?` in `s/coll-of`:

```
(def number-or-string-collection? (s/coll-of number-or-string?))
```

Output

```
#'user/number-or-string-collection?
```

Now `number-or-string-collection?` will validate that every element in the collection is either a number or a string.

The following vector passes because it only contains numbers and strings:

```
(s/valid? number-or-string-collection? [1 "Hi" "India" 42])
```

Output

```
true
```

The following vector fails because it contains a keyword (`:keyword`):

```
(s/valid? number-or-string-collection? [1 "Hi" "India" 42 :keyword])
```

Output

```
false
```

11.2. Inspecting Collections

Watch video for this section here https://yu7.in/clj-collections

Let's see how to validate data within a collection. Suppose we have a vector containing a person's details: name, age, and gender.

The name should be a string: `:name string?`

The age should be a number: `:name string? :age number?`

And the gender can be represented by a keyword: `:name string? :age number? :gender keyword?`

We can use the `s/cat` [1] (concatenate) spec to ensure the collection contains these elements in this exact order:

```
(s/cat :name string? :age number? :gender keyword?)
```

Let's name this spec `valid-person-vector?`:

```
(def valid-person-vector? (s/cat :name string? :age number? :gender keyword?))
```

Output

```
user/valid-person-vector?
```

If we pass a vector with a string, a number, and a keyword, it passes:

```
(s/valid? valid-person-vector? ["Karthik" 40 :male])
```

Output

```
true
```

Otherwise, it will fail.

Now let's look at validating maps. We can use the `s/keys` [2] spec to ensure a map contains specific keys.

```
(def valid-person-map?
  (s/keys :req-un [::name
                   ::age
                   ::gender]))
```

Output

```
#'user/valid-person-map?
```

In `s/keys`, the `:req-un` argument stands for **required and unique**. This means the map must contain these keys, and only these keys are being validated here.

The double colon syntax (e.g., `::name`) is a shorthand for a namespaced keyword. It tells Clojure to use the keyword `:name` within the current namespace.

We can now use `valid-person-map?` to check a map:

```
(s/valid? valid-person-map? {:name "Karthik"
                             :age 40
                             :gender :male})
```

Output

```
true
```

The map passes because it contains the required keys `:name`, `:age`, and `:gender`.

11.3. Validating Map Values

Watch video for this section here https://yu7.in/clj-map-spec

When validating maps, we often want to ensure that specific keys exist and that their associated

values conform to certain rules.

First, we can define specs for the individual keys using `s/def`. For example, the `:name` key should map to a string:

```
(s/def ::name string?)
```

Output

```
:user/name
```

The `:age` key should map to an integer:

```
(s/def ::age int?)
```

Output

```
:user/age
```

The `:gender` key should map to a keyword:

```
(s/def ::gender keyword?)
```

Output

```
:user/gender
```

Now we can combine these into a single spec for a person using `s/keys`:

```
(s/def ::person (s/keys :req-un [::name ::age ::gender]))
```

Output

```
:user/person
```

The `::person` spec now ensures that any map it validates contains the keys `:name` (string), `:age` (integer), and `:gender` (keyword).

Let's test it:

```
(s/valid? ::person {:name "Karthik"
```

```
                    :age 40
                    :gender :male})
```

Output

```
true
```

If we change `:age` to a string `"40"`, it will fail:

```
(s/valid? ::person {:name "Karthik"
                    :age "40"
                    :gender :male})
```

Output

```
false
```

11.4. Explaining Specs

Watch video for this section here https://yu7.in/clj-exp-spec

Clojure provides the `s/explain` function, which gives a human-readable explanation of why a value failed a spec validation.

For example:

```
(s/explain number? "42")
```

Output

```
"42" - failed: number?
```

When a spec passes, `s/explain` simply returns `Success!`:

```
(s/explain number? 42)
```

Output

```
Success!
```

```
(s/explain number-or-string? "56")
```

Output

```
Success!
```

If we test a keyword against the `number-or-string?` spec, we can see specifically which parts of the `or` spec failed:

```
(s/explain number-or-string? :56)
```

Output

```
:56 - failed: number? at: [:number]
:56 - failed: string? at: [:string]
nil
```

And if the value is a number, it passes:

```
(s/explain number-or-string? 56)
```

Output

```
Success!
nil
```

11.5. Conformity

Watch video for this section here https://yu7.in/clj-spec-fun

The `s/conform` function checks if data conforms to a spec. If it does, it returns the value:

```
(s/conform number? 42)
```

Output

```
42
```

If the data does not conform to the spec, `s/conform` throws a `clojure.spec.alpha/invalid` exception:

```
(s/conform number? "42")
```

Output

```
clojure.spec.alpha/invalid
```

```
(s/conform number-or-string? :56)
```

Output

```
:clojure.spec.alpha/invalid
```

11.6. Using Specs in Functions

Watch video for this section here https://yu7.in/clj-spec-fun

Why use specs? In Clojure, we typically use simple data types (vectors, maps, sets) rather than complex objects. When functions rely on these simple types, it becomes important to verify the integrity and conformity of the data. Specs provide a powerful way to achieve this.

Consider the following example:

```
(defn add-two-numbers [a b]
  {:pre [(s/valid? number? a)
         (s/valid? number? b)]}
  (+ a b))
```

Calling the function with valid numbers:

```
(add-two-numbers 3 5)
```

Output

```
8
```

Calling the function with an invalid argument:

```
(add-two-numbers 3 "5")
```

Output

```
; Execution error (AssertionError) at user/add-two-numbers (REPL:100).
; Assert failed: (s/valid? number? b)
```

The `:pre` hook checks if arguments `a` and `b` are numbers. If the validation fails, the function body does not execute.

Similarly, you can use the `:post` hook to verify the integrity of the returned data, ensuring that the results do not cause issues further down the line in your application.

[1] https://clojuredocs.org/clojure.spec.alpha/cat

[2] https://clojuredocs.org/clojure.spec.alpha/keys

Chapter 12. atom

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/atom.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Watch video for this section here https://yu7.in/clj-atom

Clojure is a functional programming language, meaning it primarily deals with functions. For example, $f(x) = 2x + 3$ is a function. It remembers nothing. If you plug in a value, say $x = 7$, you will get an output of 17. That is all; it is a pure function.

In the real world, however, you need to store state, and Clojure provides a way to do this. This introduces impurity into the language. In a strictly pure functional language, there would be no way to maintain state between calls. Essentially, a completely pure program would not be able to interact with the outside world, making it practically useless.

Clojure provides a way to store values in memory that persist across function calls; these are called atoms. Think of them as a global library that stores essential facts needed to run a system, such as railway, bus, and aircraft timetables.

To start, let's define an atom as shown below:

```
(def counter (atom 0))
```

As with most definitions in Clojure, we start with `(def ⋯)`, followed by the name of the atom. In this case, we call it `counter`:

```
(def counter ....)
```

We need to tell Clojure that this is not an ordinary variable but an atom. To do this, we use the `atom` function:

```
(def counter (atom .......))
```

Now we assign an initial value; let's assign 0 to it:

```
(def counter (atom 0))
```

And so we have defined our `counter` atom.

I am not sure why they call storage things as atom in Clojure.

To retrieve the value of an atom, we use the `@` (dereference) operator. To get the value of the `counter`

atom, we use:

```
@counter
```

Output

```
0
```

It correctly returns 0.

However, if we reference `counter` without the `@` operator, it returns the atom object itself rather than its value:

```
counter
```

Output

```
#object[clojure.lang.Atom 0x537d2c4f {:status :ready, :val 0}]
```

The `swap!` function allows us to update an atom. It accepts a function as its second argument, which defines how the atom's value should be changed. In the example below, the second argument is the `inc` function, which increments the value of the atom:

```
(swap! counter inc)
```

Output

```
1
```

Once executed, the value of `@counter` becomes 1. We can verify this by running the following code:

```
@counter
```

Output

```
1
```

We can change the value of an atom to any specific value using the `reset!` function. Below, we change the value of `counter` to 42:

```
(reset! counter 42)
```

Output

```
42
```

```
@counter
```

Output

```
42
```

Now, let's define an atom called `robo-count` to keep track of the number of robots created:

```
(def robo-count (atom 0))
```

Now, let's define a function named `make-robot`:

```
(defn make-robot [])
```

Whenever `make-robot` is called, it will increment `robo-count` by 1:

```
(defn make-robot []
  (swap! robo-count inc))
```

Finally, we return a string indicating the total number of robots created:

```
(defn make-robot []
  (swap! robo-count inc)
  (str "Made a robot. Total robots: " @robo-count))
```

Let's run it:

```
(make-robot)
```

Output

```
"Made a robot. Total robots: 1"
```

Let's run it two more times:

```
(make-robot)
```

Output

```
"Made a robot. Total robots: 2"
```

```
(make-robot)
```

Output

```
"Made a robot. Total robots: 3"
```

The global `robo-count` atom keeps track of the total number of robots. Since it is accessible from anywhere in the code, we can print its value as follows:

```
(println (str "Robots made: " @robo-count))
```

Output

```
Robots made: 3
```

Chapter 13. What is Clojure code

Watch the video for this section here: https://yu7.in/clj-code

Clojure is a dialect of Lisp. Lisp stands for "List Processing." In Clojure, almost all code is represented as a list data structure. In Lisp, a program is a data structure, and a data structure can be treated as a program, which gives it enormous power.

Clojure's code follows one consistent pattern:

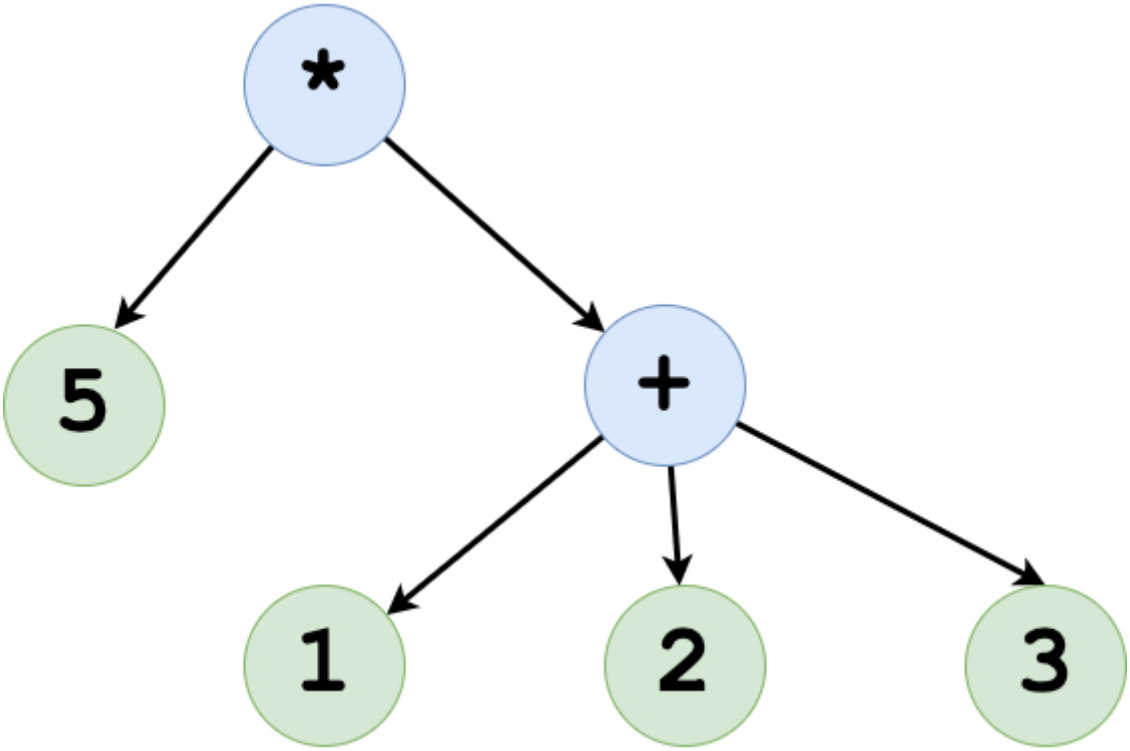
```
(function-name argument-1 .... argument-n)
```

As seen above, everything is enclosed in `(` and `)`, which represents a list data structure. As a list-processing language, Clojure is designed specifically to process these structures.

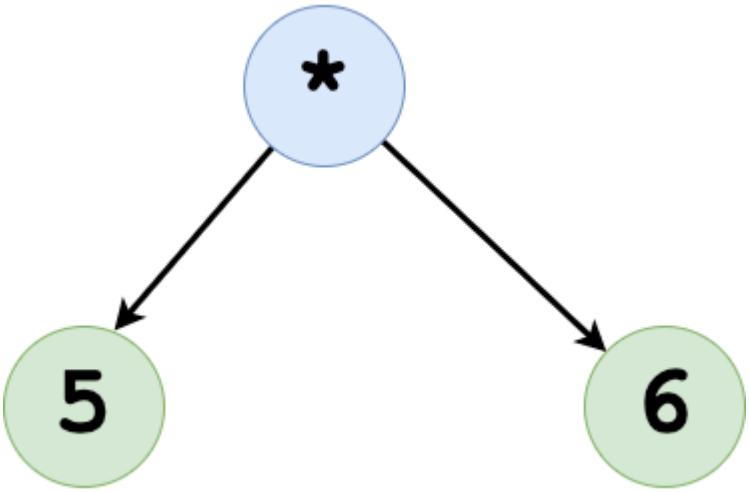
Let's consider the following example:

```
(* 5 (+ 1 2 3))
```

The above list can be represented as follows: the `*` function receives two arguments—the first is `5` and the second is `(+ 1 2 3)`. This can be diagrammatically represented as follows:



Now look at the deepest blue dots: `1`, `2`, and `3`. They feed into the `+` function and are reduced to `6`, resulting in a new data structure:



This can be written as:

```
(* 5 6)
```

In this expression, `5` and `6` are fed into the `*` function, which multiplies them, resulting in `30`.

Because Clojure is a Lisp, it has excellent uniformity in its code. Unlike Object-Oriented languages, you don't need to remember complex syntax; it is light on your brain, freeing your neurons to tackle the business problems.

Chapter 14. Sequence

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/sequence.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Watch video for this section here https://yu7.in/clj-sequence

In Clojure, `count` counts the number of elements in a list.

```
(count '(1 2 3 4))
```

Output

```
4
```

It counts the number of elements in a vector.

```
(count [1 2 3 4])
```

Output

```
4
```

It also works for sets.

```
(count #{1 2 3 4})
```

Output

```
4
```

And for maps too.

```
(count {:one 1 :two 2 :three 3 :four 4})
```

Output

```
4
```

You might wonder whether `count` checks the type of the argument and calls a different algorithm for each type, or if it simply converts the argument into a common data type before counting.

There is a function called `seq` [1], which converts all the above data types to a sequence:

```
(seq '(1 2 3 4))
```

Output

```
(1 2 3 4)
```

```
(seq [1 2 3 4])
```

Output

```
(1 2 3 4)
```

```
(seq #{1 2 3 4})
```

Output

```
(1 4 3 2)
```

```
(seq {:one 1 :two 2 :three 3 :four 4})
```

Output

```
([:one 1] [:two 2] [:three 3] [:four 4])
```

Now all `count` needs to do is count the elements in a sequence as shown:

```
(count '(1 2 3 4))
```

Output

```
4
```

```
(count '([:one 1] [:two 2] [:three 3] [:four 4]))
```

Output

```
4
```

Now think about `partition` and other functions that work on collections and try it for yourself:

```
(seq [1 2 3])
```

Output

```

```

```
(seq '(1 2 3))
```

Output

```

```

```
(seq #{1 2 3})
```

Output

```

```

```
(seq {1 "one" 2 "two" 3 "three"})
```

Output

```

```

```
(partition 2 {1 "one" 2 "two" 3 "three" 4 "four"})
```

Output

```

```

```
(partition 2 (seq {1 "one" 2 "two" 3 "three" 4 "four"}))
```

Output

```

```

```
(partition 2 '(1 2 3 4))
```

Output

```

```

```
(partition 2 (seq '(1 2 3 4)))
```

Output

```

```

```
(partition 2 #{1 2 3 4})
```

Output

```

```

```
(partition 2 (seq #{1 2 3 4}))
```

Output

```

```

```
(partition 2 [1 2 3 4])
```

Output

```

```

```
(partition 2 (seq [1 2 3 4]))
```

Output

Do you think `partition` implements several algorithms, say one for list, one for vector and so on? Or it has a smarter implementation?

[1] https://clojuredocs.org/clojure.core/seq

Chapter 15. Lazy Sequence

Watch video for this section here https://yu7.in/clj-lzseq

Some sequences are evaluated only when they need to be, and these are called lazy sequences. For example, you can easily create a lazy sequence of infinite numbers without your computer crashing.

Think of it this way: when someone mentions "infinity," your brain doesn't crash; it simply understands the concept of infinity and how it fits into mathematics. When you need to use it in a specific context, such as calculus, you are still able to apply and use it.

15.1. repeat

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/lazy_sequence_repeat.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Let's take a look at the `repeat` function. Take a look at the code below:

```
(def multiverse (repeat "universe"))
```

In the above code, we are creating a variable named `multiverse` which contains many instances of `"universe"`; theoretically, it is infinite. Treating it as a sequence, let's take the first element:

```
(first multiverse)
```

Output

```
"universe"
```

And we get `"universe"`. Now let's take 5 elements from it:

```
(take 5 multiverse)
```

Output

```
("universe" "universe" "universe" "universe" "universe")
```

We get 5 universes. Let's get the `rest` of the sequence:

```
(rest multiverse) ;; doesn't seem to work
```

This throws an error. After all, how can you get the rest of an infinite sequence?

Similarly, `last` also throws an error; how can you get the last element of an infinite sequence?

```
(last multiverse) ;; doesn't seem to work
```

Now let's get the 10,001st element:

```
(nth multiverse 10000)
```

Output

```
"universe"
```

Let's get the 101st element:

```
(nth multiverse 100)
```

Output

```
"universe"
```

The `repeat` function doesn't only create infinite sequences; we can create a finite sequence by telling Clojure how many times to repeat. The code below creates only five instances of `"universe"`:

```
(repeat 5 "universe")
```

Output

```
("universe" "universe" "universe" "universe" "universe")
```

If we try to access the 7th element, it throws an exception:

```
(nth (repeat 5 "universe") 6)
```

Output

```
; Execution error (IndexOutOfBoundsException) at user/eval2056 (REPL:11).
```

```
; null
```

Since there are only 5 elements in `(repeat 5 "universe")`, the code below retrieves the 4th element, which works.

```
(nth (repeat 5 "universe") 3)
```

Output

```
"universe"
```

Since `(repeat 5 "universe")` has a finite number of elements, `rest` works on it without raising any exceptions:

```
(rest (repeat 5 "universe"))
```

Output

```
("universe" "universe" "universe" "universe")
```

Similarly, `last` also works on it:

```
(last (repeat 5 "universe"))
```

Output

```
"universe"
```

15.2. cycle

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/lazy_sequence_cycle.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Watch video for this section here https://yu7.in/clj-cycle

Let's say you want to go through a sequence in a cyclical manner; then `cycle` is the function to use. Take a look at the code below:

```
(def multiverse (cycle ["universe" "antiverse"]))
```

Output

```
#'user/multiverse
```

The above code creates an infinite sequence and assigns it to the variable `multiverse`, where every even-indexed element (0, 2, 4, ...) is `"universe"` and every odd-indexed element (1, 3, 5, ...) is `"antiverse"`. Thus, the first element is `"universe"`:

```
(first multiverse)
```

Output

```
"universe"
```

The second element is `"antiverse"`:

```
(second multiverse)
```

Output

```
"antiverse"
```

If we take 5 elements, they alternate between `"universe"` and `"antiverse"`, as shown:

```
(take 5 multiverse)
```

Output

```
("universe" "antiverse" "universe" "antiverse" "universe")
```

We can take any element at an even index, and it will be `"universe"`:

```
(nth multiverse 2000)
```

Output

```
"universe"
```

Similarly, any element at an odd index will be `"antiverse"`:

```
(nth multiverse 1783)
```

Output

```
"antiverse"
```

Now let's cycle some South Indian tiffin items:

```
(def tiffin-items
  (cycle ["idli", "vadai", "dosai", "sambar"]))
```

Output

```
#'user/tiffin-items
```

Let's take the 6th element:

```
(nth tiffin-items 5)
```

Output

```
"vadai"
```

The last element, `"sambar"`, is at index 3. Therefore, the 0th element repeats at index 4, the 1st at index 5, and so on, creating a never-ending loop.

Now let's take 10 `tiffin-items` to see how it repeats:

```
(take 10 tiffin-items)
```

Output

```
("idli" "vadai" "dosai" "sambar" "idli" "vadai" "dosai" "sambar" "idli" "vadai")
```

15.3. iterate

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/lazy_sequence_iterate.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Watch video for this section here https://yu7.in/clj-iterate

`iterate` is a powerful function in Clojure. Let's look at an example:

```
(def all-numbers (iterate inc 1))
```

Output

```
#'user/all-numbers
```

In the above code, we have `(iterate inc 1)`. In other words, `iterate` takes a function (like `inc`) as its first argument and a starting value as its second. This is assigned to `all-numbers`. Now let's see what happens when we take the 25th element:

```
(nth all-numbers 24)
```

Output

```
25
```

The output looks as if we applied `inc` to 1 twenty-four times.

Now let's take the first 10 elements:

```
(take 10 all-numbers)
```

Output

```
(1 2 3 4 5 6 7 8 9 10)
```

The first element, 1, is the starting value passed to `iterate`. The second is `(inc 1)`, the third is `(inc (inc 1))`, and so on. This is consistent with the `iterate` documentation: https://clojuredocs.org/clojure.core/iterate.

Now let's create a function that squares a number:

```
(defn squared [num]
  (Math/pow num 2))
```

Output

```
#'user/squared
```

Now let's iterate through the squares of 5:

```
(def squares (iterate squared 5))
```

Output

```
#'user/squares
```

Now let's take the first three squares:

```
(take 3 squares)
```

Output

```
(5 25.0 625.0)
```

Here is the explanation:

The first value, `5`, is the starting argument passed to `iterate` in `(def squares (iterate squared 5))`; it is returned as-is.

The second value, `25.0`, is the result of the first iteration: `(squared 5)`.

The third value, `625.0`, is the result of the second iteration: `(squared (squared 5))`.

Chapter 16. map, filter, reduce, apply

16.1. map

Watch video for this section here https://yu7.in/clj-map

Let's say you have a function that acts on an argument, such as `inc` (where `(inc 1)` gives 2). To apply `inc` to every element in a collection or sequence, you can use `map`. Simply pass the function to `map`, followed by the collection, as shown:

```
(map inc [1 2 3])
```

Output

```
(2 3 4)
```

In this case, `map` applies the `inc` function to each element of `[1 2 3]`, collects the results into a sequence, and returns it. This results in `(2 3 4)` as the output.

In the example below, I pass an anonymous function `(fn [x] (+ x 1))` to `map` and apply it to `[1 2 3]`:

```
(map (fn [x] (+ x 1)) [1 2 3])
```

Output

```
(2 3 4)
```

This demonstrates that you don't need a predefined function; in Clojure, you can define small functions on the fly.

The following code works the same way as the previous examples:

```
(map #(+ % 1) [1 2 3])
```

Output

```
(2 3 4)
```

Another way to write the anonymous function `(fn [x] (+ x 1))` is `(+ % 1)`. The function body is enclosed in `()`, and `%` represents the argument passed to the function. This shorthand is often more concise than `(fn [x] (+ x 1))`.

Let's say we have a function that takes two arguments:

```
(fn [x y]
  (+ (Math/pow x 2)
    (Math/pow y 2)))
```

This function takes two arguments and returns the sum of their squares. How do we make this function work with sequences? Simply pass it to `map` as shown:

```
(map (fn [x y]
       (+ (Math/pow x 2)
          (Math/pow y 2))))
```

Next, pass the sequence for the first argument (`x`):

```
(map (fn [x y]
       (+ (Math/pow x 2)
          (Math/pow y 2))) [1 2 3])
```

Then, pass the sequence for the second argument (`y`):

```
(map (fn [x y]
       (+ (Math/pow x 2)
          (Math/pow y 2))) [1 2 3] [2 3 4])
```

Output

```
(5.0 13.0 25.0)
```

The code works as follows: `map` takes the first element from `[1 2 3]` (which is `1`) and the first element from `[2 3 4]` (which is `2`) and passes them to:

```
(fn [x y]
  (+ (Math/pow x 2)
    (Math/pow y 2)))
```

The function calculates the sum of squares and returns `5.0`. `map` collects this into a sequence, resulting in `(5.0)`.

Then `map` takes the second element from each sequence (`2` and `3`), and the function returns `13.0`, which is appended to the result sequence. This process is repeated for the third elements, adding `25.0` to the sequence. The final result `(5.0 13.0 25.0)` is then returned.

In the sample below I have a function called sum-of-squares:

```
(defn sum-of-squares [x y]
  (+ (Math/pow x 2)
     (Math/pow y 2)))
```

This is simply giving a name to the anonymous function:

```
(fn [x y]
  (+ (Math/pow x 2)
    (Math/pow y 2)))
```

used previously. We use the name `sum-of-squares` with `map` and pass two sequences for `x` and `y` to get the same result:

```
(map sum-of-squares [1 2 3] [2 3 4])
```

Output

```
(5.0 13.0 25.0)
```

The following function, `double-it`, doubles the number passed to it:

```
(defn double-it [x]
  (* x 2))
```

Output

```
#'user/double-it
```

Let's use it with `map` to double the numbers in a vector:

```
(map double-it [1 2 3])
```

Output

```
(2 4 6)
```

16.2. filter

Watch video for this section here https://yu7.in/clj-filter

`filter` returns a sequence containing only the elements of the original sequence for which the given predicate function returns `true`. For example, `(odd? 1)` returns `true`, whereas `(odd? 2)` returns `false`. Look at the code below:

```
(filter odd? (range 1 11))
```

Output

```
(1 3 5 7 9)
```

In this example, we pass `odd?` as the first argument and a sequence of numbers from 1 to 10 (generated by `(range 1 11)`) as the second. Any number for which `odd?` returns `true` is kept by `filter` and included in the result.

Similarly, the example below returns only the even numbers:

```
(filter even? (range 1 11))
```

Output

```
(2 4 6 8 10)
```

In the code below:

```
(filter #(> % 5) (range 1 11))
```

Output

```
(6 7 8 9 10)
```

Here, we pass an anonymous function `#(> % 5)` to `filter`. Any number between 1 and 10 that is greater than 5 is returned.

In the example below, all numbers from 1 to 10 that are less than 5 are returned:

```
(filter #(> 5 %) (range 1 11))
```

Output

```
(1 2 3 4)
```

```
(filter (fn [x] (> x 5)) (range 1 11))
```

Output

```
(6 7 8 9 10)
```

Below, I define a function called `greater-than-5`, which returns `true` if a number is greater than 5:

```
(defn greater-than-5 [x]
  (> x 5))
```

I then use it with `filter` to find numbers greater than 5:

```
(filter greater-than-5 (range 1 11))
```

Output

```
(6 7 8 9 10)
```

16.3. reduce

Watch video for this section here https://yu7.in/clj-reduce

`reduce` reduces a sequence to a single value by repeatedly applying a function to the current accumulator and the next element of the sequence. Take the example below:

```
(reduce + [1 2 3 4])
```

Output

```
10
```

We pass the `+` function and the sequence `[1 2 3 4]` to `reduce`. You can think of `reduce` as rewriting the code like this:

```
(+ 4 (+ 3 (+ 1 2)))
```

This reduces the sequence to the single value 10.

Here is how to multiply the elements of a sequence using `reduce`:

```
(reduce * [1 2 3 4])
```

Output

```
24
```

Let's define a function called `add` that accepts two numbers and returns their sum:

```
(defn add [a b]
  (+ a b))
```

Output

```
#'user/add
```

We can use it with `reduce`, just as we did with `+` previously:

```
(reduce add [1 2 3 4])
```

Output

```
10
```

Similarly, `reduce` effectively rewrites the code as follows:

```
(add 4 (add 3 (add 1 2)))
```

Similarly, I have defined a `multiply` function:

```
(defn multiply [a b]
  (* a b))
```

Output

```
#'user/multiply
```

and used it with `reduce`:

```
(reduce multiply [1 2 3 4])
```

Output

```
24
```

16.4. apply

Watch the video for this section here: https://yu7.in/clj-apply

The `+` function can add multiple numbers as follows:

```
(+ 1 2 3 4)
```

Output

```
10
```

However, if you pass a sequence as a single argument, the operation will fail:

```
(+ [1 2 3 4]) ;; error
```

Output

```
; Execution error (ClassCastException) at java.lang.Class/cast (Class.java:3921).
; Cannot cast clojure.lang.PersistentVector to java.lang.Number
```

To fix this, we pass the `+` function and the sequence to `apply`:

```
(apply + [1 2 3 4])
```

Output

```
10
```

This works because `apply` effectively expands the sequence into individual arguments, rewriting the code as follows:

```
(+ 1 2 3 4)
```

A sequence can be a vector, list, or map. In this example, we use `apply` with a list of numbers:

```
(apply + '(1 2 3 4))
```

Output

```
10
```

Consider a function that takes two arguments and prints them both:

```
(defn my-function [arg1 arg2]
  (println "Argument 1:" arg1)
  (println "Argument 2:" arg2))
```

Output

```
#'user/my-function
```

We can call this function by providing two arguments:

```
(my-function "one" "two")
```

Output

```
Argument 1: one
Argument 2: two
nil
```

If we pass a vector containing two elements instead of two separate arguments, the function call will fail:

```
(my-function ["one" "two"]) ;; error
```

Output

```
; Execution error (ArityException) at user/eval2061 (REPL:17).
; Wrong number of args (1) passed to: user/my-function
```

To resolve this, we pass the function and the sequence to `apply`:

```
(apply my-function ["one" "two"])
```

Output

```
Argument 1: one
Argument 2: two
nil
```

Chapter 17. Destructuring

Watch the video for this section here: https://yu7.in/clj-destructuring

Clojure provides a rich variety of data types to pack your data, such as lists, vectors, maps, and sets. To perform computations with them, you need to unpack the data, assign the necessary values to variables, and use those variables in your computation. This section explains how to do this.

Take a look at the program `vector_destructuring.clj` shown below; type it and execute it:

```
;; vector_destructuring.clj

(def people ["Rehmaan" "Kalaam"])

(let [[musician scientist] people]
  (println "Musician is" musician)
  (println "Scientist is" scientist))
```

Output

```
Musician is Rehmaan
Scientist is Kalaam
nil
```

In the line `(def people ["Rehmaan" "Kalaam"])`, we pack `"Rehmaan"` and `"Kalaam"` into a vector and name it `people`. Now consider:

```
(let [[musician scientist] people]
  ;; other code goes here
 )
```

In the `let` expression, look at `[[musician scientist] people]`. The variables `musician` and `scientist` point to `people`. Clojure determines that `people` contains `"Rehmaan"` and `"Kalaam"`, then unpacks `"Rehmaan"` into `musician` and `"Kalaam"` into `scientist`. Finally, we print `musician` and `scientist` using the `println` function as shown below:

```
(let [[musician scientist] people]
  (println "Musician is" musician)
  (println "Scientist is" scientist))
```

Take a look at the code in `vector_destructuring_2.clj` below; type it and execute it.

```
;; vector_destructuring_2.clj
```

```
(def people ["Rehmaan" "Kalaam"])

(let [[musician scientist artist] people]
  (println "Musician is" musician)
  (println "Scientist is" scientist)
  (println "Artist is" artist))
```

Output

```
Musician is Rehmaan
Scientist is Kalaam
Artist is nil
nil
```

In the code above, we see that the variable `people` is assigned to a vector containing only two values: `["Rehmaan" "Kalaam"]`. However, in the `let` block, we are attempting to destructure it into three variables: `musician`, `scientist`, and `artist`, as shown:

```
(let [[musician scientist artist] people]
  ;; other stuff goes here
  )
```

In this case, the first two variables, `musician` and `scientist`, are populated with `"Rehmaan"` and `"Kalaam"` respectively, while `artist` is assigned `nil`. Consequently, when printed, `artist` results in `nil`.

Now look at the code in `vector_destructuring_3.clj` shown below; type it and execute it.

```
;; vector_destructuring_3.clj

(def people ["Rehmaan" "Kalaam" "Hussein" "Madhavan"])

(let [[musician scientist artist] people]
  (println "Musician is" musician)
  (println "Scientist is" scientist)
  (println "Artist is" artist))
```

Output

```
Musician is Rehmaan
Scientist is Kalaam
Artist is Hussein
nil
```

In the code above, there are four values in `people`, but it is being destructured into only three

variables:

```
(let [[musician scientist artist] people]
  ;; other code goes here
  )
```

As a result, `musician` is populated with `"Rehmaan"`, `scientist` with `"Kalaam"`, and `artist` with `"Hussein"`, while the final value in `people`, `"Madhavan"`, is ignored.

In the code below:

```
;; vector_destructuring_4.clj

(def people ["Rehmaan" "Kalaam" "Hussein" "Madhavan"])

(let [[musician scientist artist actor] people]
  (println "Musician is" musician)
  (println "Scientist is" scientist)
  (println "Artist is" artist)
  (println "Actor is" actor))
```

Output

```
Musician is Rehmaan
Scientist is Kalaam
Artist is Hussein
Actor is Madhavan
nil
```

All values in `people` are now unpacked correctly into the variables `musician`, `scientist`, `artist`, and `actor`.

It is a convention to use an underscore `_` for values that will not be used. In the code below, only `scientist` and `actor` are needed; the other unused values are captured by `_`.

```
;; vector_destructuring_5.clj

(def people ["Rehmaan" "Kalaam" "Hussein" "Madhavan"])

(let [[_ scientist _ actor] people]
  (println "Scientist is" scientist)
  (println "Actor is" actor))
```

Output

```
Scientist is Kalaam
```

```
Actor is Madhavan
nil
```

This signals to anyone reading the code that these values are intentionally ignored.

While the examples above demonstrate vector destructuring, the same logic applies to lists. Readers are encouraged to try this out.

Clojure also provides a way to destructure maps. See the code in `map_destructuring.clj` below; type it and execute it.

```
;; map_destructuring.clj

(def people
  {:musician "Rehmaan"
   :scientist "Kalaam"
   :artist "Hussein"
   :actor "Madhavan"})

(let [{scientist :scientist actor :actor} people]
  (println "Scientist is" scientist)
  (println "Actor is" actor))
```

Output

```
Scientist is Kalaam
Actor is Madhavan
nil
```

If you look at:

```
(def people
  {:musician "Rehmaan"
   :scientist "Kalaam"
   :artist "Hussein"
   :actor "Madhavan"})
```

We have a map of people, where their profession is the keyword and their name is the string. This map can be destructured using keywords, as shown:

```
(let [{scientist :scientist actor :actor} people]
    ;; other stuff here
  )
```

In the code above, notice the expression `[{scientist :scientist actor :actor} people]`; here, the map destructuring pattern `{scientist :scientist actor :actor}` is applied to `people`.

The pattern `{scientist :scientist actor :actor}` looks like a map in reverse. The variable `scientist` followed by the keyword `:scientist` extracts the value associated with `:scientist` from the map and assigns it to the variable `scientist`. The variable `actor` is assigned in the same way.

This makes it very easy to selectively extract values from a map and assign them to variables in Clojure.

Chapter 18. Threading Macros

If you come from other programming languages, don't confuse threading with threads (which refers to executing chunks of code in parallel). In Clojure, threading refers to a way of writing code that makes sequences of operations more intuitive. This will become clearer as you read this chapter.

18.1. Thread First

Consider the following program and run it:

```
(-> 5
    (Math/pow 2))
```

Output

```
25.0
```

The output is 25.0. From this, you might guess that Clojure effectively rewrites your program as follows:

```
(Math/pow 5 2)
```

The `->` macro is called 'thread-first'. This means that if you write:

```
(-> 5)
```

And then follow it with a function, such as `Math/pow`:

```
(-> 5
    (Math/pow 2))
```

The thread-first macro will place `5` as the first argument to the function `Math/pow`. It becomes equivalent to:

```
(Math/pow 5 2)
```

Now consider the code below, where `5` is passed as the first argument to `(Math/pow 2)` and then to `inc`. Execute the program:

```
(-> 5
```

```
    (Math/pow 2)
    inc)
```

Output

```
26.0
```

It gives `26.0` as output. The first step of the program can be rewritten as:

```
(-> (Math/pow 5 2)
    inc)
```

Now, the result of `(Math/pow 5 2)` is passed as the first argument to `inc`, and the code becomes:

```
(inc (Math/pow 5 2))
```

So it gives an output of 26.0.

Consider this program and execute it:

```
(-> 10
    inc
    (* 2)
    (+ 5))
```

Output

```
27
```

It can be rewritten as:

```
(+ (* (inc 10) 2) 5)
```

Which when executed gives 27.

18.2. Thread Last

While thread-first places the threaded value as the first argument to a function, thread-last (`->>`) places it as the last argument. Let's look at an example.

Execute the code below:

```
(->> 5
    (Math/pow 2))
```

Output

```
32.0
```

Since `5` is passed to the thread-last macro `->>`, the code above is equivalent to:

```
(Math/pow 2 5)
```

In other words, `5` is placed at the end of `(Math/pow 2)`, resulting in `32.0`.

Consider the following example:

```
(->> 5
     (Math/pow 2)
     inc)
```

Output

```
33.0
```

This can be rewritten as:

```
(inc (Math/pow 2 5))
```

Which evaluates to `33.0`.

18.3. Thread as

Sometimes you need to pass a threaded value at an arbitrary position within a function. In such cases, you can use the `as->` (thread-as) macro.

In the code below:

```
(as-> 5 x
  (Math/pow x 2))
```

Output

```
25.0
```

The threaded value is bound to the symbol `x`, allowing you to place `x` anywhere within the expression. In the previous example, we placed it as `(Math/pow x 2)`, calculating x^2.

In the following example:

```
(as-> 5 x
  (Math/pow 2 x))
```

Output

```
32.0
```

We pass `x` as the last argument to `Math/pow`, calculating 2^x.

18.4. Conditional Threading

If you want to thread values conditionally, you can use conditional threading. Consider the following example:

```
(let [a 11]
  (cond-> []
   (odd? a) (conj (* a 2))
   (even? a) (conj (/ a 2))))
```

Output

```
[22]
```

The `cond->` macro is the conditional thread-first operator. In this case, we pass an empty vector `[]` to it:

```
(let [a 11]
  (cond-> []
   ....))
```

Following `cond-> []` are pairs of conditions and expressions. The expression is executed only if the condition is true. The code above can be rewritten as:

```
(let [a 11]
  (cond
```

```
   (odd? a) (conj [] (* a 2))
   (even? a) (conj [] (/ a 2))))
```

In this example, `a` is odd, so the expression `(conj [] (* a 2))` is executed, resulting in `[22]`.

The following example has a subtle difference: instead of the conditional thread-first macro `cond->`, we use the conditional thread-last macro `cond->>`.

Execute the following code:

```
(let [a 10]
  (cond->> 1
   (odd? a) (* a 2)
   (even? a) (/ a 2)))
```

Output

```
5
```

The code above is equivalent to:

```
(let [a 10]
  (cond
   (odd? a) (* a 2 1)
   (even? a) (/ a 2 1)))
```

Since `a` is even, the expression `(/ a 2 1)` is executed. Mathematically, this is $10 \div 2 \div 1$, which results in `5`.

Chapter 19. Regular Expression

Get source code here https://gitlab.com/clojure-book/code/-/raw/master/regular_expression.cl

Watch video for this section here https://yu7.in/clj-regexp

We know what a string is; it's a set of characters that's enclosed between " and " (double quotes). Shown below is a string:

```
"A string"
```

Output

```
"A string"
```

When we look at its type, it does tell us that it's a string:

```
(type "A string")
```

Output

```
java.lang.String
```

Now what will happen if we enclose a set of characters between `"` and `"? Below I have enclosed regexp between"` and `"`:

```
#"regexp"
```

Output

```
#"regexp"
```

When I query about its type, I find that it's a `java.util.regex.Pattern`; that is, it is not a string, it's a pattern.

```
(type #"regexp")
```

Output

```
java.util.regex.Pattern
```

Regular expressions can be used to find if certain patterns occur in a string. For example, an email address has a pattern. Say my email is mindaslab@protonmail.com: `mindaslab` is my username followed by an `@` symbol, `com` is a top-level domain, and `protonmail` is a subdomain of `com`. The subdomain and top-level domains are separated by a dot. When you see a lot of email addresses, you may think `<username>@<subdomain>.<top level domain>` is a regular expression of an email.

Similarly, if you see a lot of postal addresses, you might notice that the house number and street name appear at the top, and the pin code or zip code is at the bottom.

These regular expressions help you identify if you are looking at an email address or a postal address when they are presented to you.

Your brain has millions of years of evolution and lots of experience to recognize these things in a jiffy. For computers, we programmers must specify how to scan for patterns in a string and identify what they are.

Now let's write a regular expression to identify just one digit. It's `"\d". The"` marks the start of the regular expression and `"` marks the end. The `\d` means we are looking for just one digit. Here, the `\` is an escape sequence that makes `#"\d"` search for a digit rather than the letter `d`.

There is a function called `re-matches` which we can use to see if a string matches a regular expression. Let's see if `"There is no number here."` matches `#"\d"`:

```
(re-matches #"\d" "There is no number here.")
```

Output

```
nil
```

It doesn't as there is no number in the string.

Now let's see if `#"\d"` matches `"4"`:

```
(re-matches #"\d" "4")
```

Output

```
"4"
```

And it does, as `"4"` contains just one digit and that's what `#"\d"` searches for.

Now let's see if `#"\d"` matches `"42"`:

```
(re-matches #"\d" "42")
```

Output

```
nil
```

And it doesn't, because `"42"` contains more than one digit.

In order to specify "one or more" in a regular expression, we use the `+` symbol, so `#"\d+"` means search for one or more digits. Look at the example below:

```
(re-matches #"\d+" "42")
```

Output

```
"42"
```

It matches because `"42"` contains one or more digits.

It may be surprising that `#"\d+"` does not match `"42 is the ultimate answer."` as shown below:

```
(re-matches #"\d+" "42 is the ultimate answer.")
```

Output

```
nil
```

That's because `re-matches` checks if a string exactly matches a regular expression. `"42 is the ultimate answer."` contains `42` followed by a space and other words, which is not an exact match for `#"\d+"`, hence it returns `nil`.

In order to find a pattern in a string, we can use `re-find` as shown:

```
(re-find #"\d+" "42 is the ultimate answer.")
```

Output

```
"42"
```

This does output `"42"`, and hence we can convince ourselves it can fish out a pattern from a string.

Now let's search for 2-digit numbers as shown below:

```
(re-find #"\d+" "42 is the ultimate answer, and so is 52.")
```

Output

```
"42"
```

If you thought it would find both `"42"` and `"52"`, you would be disappointed, as you can see only `"42"` above. `re-find` returns only the first match:

```
(re-find #"\d+" "Forty two is the ultimate answer, and so is 52.")
```

Output

```
"52"
```

As you can see from the above example, `re-find` returns only the first match `"52"`.

In order to get all matches, use `re-seq`:

```
(re-seq #"\d+" "42 is the ultimate answer, and so is 52.")
```

Output

```
("42" "52")
```

This returns a sequence with all strings that match the regular expression; in our case, it's `#"\d+"`.

19.1. Case sensitive and insensitive matches

Now let's say we have regular expression `#"abc"`, this would help us to match and find letters `abc` in a string, but not `ABC`, because `ABC` are capital letters, there is a trick in regexp to make it case-insensitive. You can tell Clojure to make the regexp case-insensitive by adding `(?i)` to regexp as shown:

```
(re-seq #"(?i)abc" "abc are small letters and ABC are capitals.")
```

Output

```
("abc" "ABC")
```

So `#"(?i)abc"` matches `"abc"`, `"ABC"`, `"AbC"` and so on.

Below you can see how `#"abc"` does not match `"ABC"`:

```
(re-seq #"abc" "abc are small letters and ABC are capitals.")
```

Output

```
("abc")
```

In the example below you can see how `#"(?i)ABC"` matches `"abc"`, `"ABC"` because it's case-insensitive:

```
(re-seq #"(?i)ABC" "abc are small letters and ABC are capitals.")
```

Output

```
("abc" "ABC")
```

Another case-insensitive regular expression is `#"(?i)abC"` in action:

```
(re-seq #"(?i)abC" "abc are small letters and ABC are capitals.")
```

Output

```
("abc" "ABC")
```

19.2. Scanning for range of characters

Now let's check for ranges. Suppose you want to scan for capital letters—specifically, one or more of them. For that, you must use the `+` quantifier.

Capital letters range from A to Z, so in a regexp, you can write it as `#"[A-Z]+"`. This means "scan for one or more capital letters in the range A to Z." Let's try out an example:

```
(re-seq #"[A-Z]+" "Finds all CAPITAL letter WORDS.")
```

Output

```
("F" "CAPITAL" "WORDS")
```

It seems to work.

19.3. Using with string functions

Some string functions in Clojure accept regular expressions too, let's see them in action.

First, we require the Clojure string library as `str`:

```
(require '[clojure.string :as str])
```

In the code below, we have lots of spaces in `"There are lots of spaces"`. We create a regular expression `#"\s+"`, which means "one or more whitespace characters." We then tell the `replace` function to replace one or more spaces with a single space `" "`:

```
(str/replace "There    are     lots of   spaces" #"\s+" " ")
```

Output

```
"There are lots of spaces"
```

It works.

In the code below we use a split function:

```
(str/split "There   are     lots of   spaces" #"\s")
```

Output

```
["There" "" "" "are" "" "" "" "" "lots" "of" "" "" "spaces"]
```

We tell the `split` to split `"There are lots of spaces"` with a single space `#"\s"` so we get what we get above, I think this is not the intended result. What we should have done is to tell it to split with one or more spaces as shown below:

```
(str/split "There   are     lots of   spaces" #"\s+")
```

Output

```
["There" "are" "lots" "of" "spaces"]
```

We get a nice split where the words are split.

19.4. Things to remember

There are some things you need to remember, or at least refer from time to time when you want to use regular expressions. Those are mentioned in table below [1].

Thing	What it means
.	Any single character
\w	Any word character (letter, number, underscore)
\W	Any non-word character
\d	Any digit
\D	Any non-digit
\s	Any whitespace character
\S	Any non-whitespace character
\b	Any word boundary character
^	Start of line
$	End of line
\A	Start of string
\z	End of string
[abc]	A single character of
a, b or c	[^abc]
Any single character except	a, b, or c
[a-z]	Any single character in the range a-z
[a-zA-Z]	Any single character in the range a-z or A-Z
(…)	Capture everything enclosed
(a|b)	a or b
a?	Zero or one of a
a*	Zero or more of a
a+	One or more of a
a{3}	Exactly 3 of a
a{3,}	3 or more of a
a{3,6}	Between 3 and 6 of a
i	case-insensitive
m	make dot match newlines
x	ignore whitespace in regex
o	perform #{…} substitutions only once

Don’t panic if you don’t understand it, you will catch up.

19.5. Lots more left out

Regular expressions are a huge topic, and this book provides just an introduction. It introduces the concept of regular expressions, and that’s it. I will try to add more content in upcoming releases. To learn more, you can refer to **Mastering Regular Expressions** (https://amzn.to/3YvByJM) and the **Regular Expression Pocket Reference** (https://amzn.to/3DNXvtQ).

[1] I got this list from http://rubular.com/

Chapter 20. Splitting Large Programs

Watch video for this section here https://yu7.in/clj-slp

A very small, one-line Clojure script can be written in a Clojure REPL, and a larger one can be written in a file. But what happens when a script becomes too large for a single file and becomes difficult to manage? You can split it into multiple files. This section explains how to load scripts from one file into another in your Clojure code.

For example, let's say you have a program as shown below:

https://gitlab.com/clojure-book/code/-/raw/master/calculator.clj(calculator.clj)

```
;; calculator.clj

(defn add [a b]
  (+ a b))

(defn sub [a b]
  (- a b))

(def a 5)
(def b 3)

(println a " + " b " = " (add a b))
(println a " - " b " = " (sub a b))
```

Output

```
5  +  3  =  8
5  -  3  =  2
```

This works fine, but you'll notice that one file is doing two different things. First, it defines the calculation functions `add` and `sub`:

```
(defn add [a b]
  (+ a b))

(defn sub [a b]
  (- a b))
```

Then, it uses those functions to compute a result:

```
(def a 5)
(def b 3)
```

```
(println a " + " b " = " (add a b))
(println a " - " b " = " (sub a b))
```

Wouldn't it be better to split this into two different files? We can move the function definitions into a file called `calc_lib.clj`:

```
;; calc_lib.clj

(defn add [a b]
  (+ a b))

(defn sub [a b]
  (- a b))
```

Then, in another file called `calc_ui.clj`, we write the following code:

```
;; calc_ui.clj

(load-file "calc_lib.clj")

(def a 5)
(def b 3)

(println a " + " b " = " (add a b))
(println a " - " b " = " (sub a b))
```

Notice the line `(load-file "calc_lib.clj")`; this loads the `calc_lib.clj` file into `calc_ui.clj`. Now we can compute the result of adding and subtracting 5 and 3.

By separating the calculation functions into their own file, you can include them in any other file where you need to perform additions or subtractions. This significantly increases reusability.

Chapter 21. Records and Protocols

Clojure emerged during an era when Object-Oriented Programming (OOP) was at its peak. Over time, as codebases grew increasingly large and complex, some of the shortcomings of OOP became apparent, leading many to explore functional programming. It is therefore not surprising that Clojure provides ways to create objects and interact with them.

In Clojure, an object is essentially a glorified map—nothing more. While you might not always need them, they are available for your use.

21.1. Creating Objects

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/record.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Watch the video for this section here: https://yu7.in/clj-records

Objects in Clojure are called Records. Let's create our first record, called `Car`, which will hold the `name` and `top-speed` of a car:

```
(defrecord Car [name top-speed])
```

Output

```
user.Car
```

As you can see from the output, this creates something called `user.Car`. `user` is the default namespace, and `Car` represents the record. If `Car` were just a variable, the output would have been something like `user/Car`.

Now let's define a variable called `tata-nano`:

```
(def tata-nano)
```

Of the type `Car`:

```
(def tata-nano (->Car))
```

When we created the `Car` record, we specified `name` first and then `top-speed`. Following that same order, let's give a name to `tata-nano`:

```
(def tata-nano (->Car "Tata Nano"))
```

And specify its top speed as `120`:

```
(def tata-nano (->Car "Tata Nano" 120))
```

Let's now execute the code above:

```
(def tata-nano (->Car "Tata Nano" 120))
```

Output

```
#'user/tata-nano
```

A variable `tata-nano` has been created in the `user` namespace. This is not a simple value, but an object containing two values.

Since an object in Clojure is a glorified map, you can access the `:name` of `tata-nano` just as you would with a map:

```
(:name tata-nano)
```

Output

```
"Tata Nano"
```

```
(get tata-nano :name)
```

Output

```
"Tata Nano"
```

Similarly, you can access its top speed:

```
(:top-speed tata-nano)
```

Output

```
120
```

```
(get tata-nano :top-speed)
```

Output

```
120
```

Similarly, let's create another instance of the `Car` record called `ambassador`, but notice the difference in the code below:

```
(def ambassador (map->Car {:name "Ambassador",
                           :top-speed 240 }))
```

Output

```
#'user/ambassador
```

When creating `tata-nano`, we provided the values positionally. However, look at `map→Car`. Instead of `→Car`, we are specifying that we want to pass a map, so we provide this map:

```
{ :name "Ambassador",
  :top-speed 240 }
```

Clojure automatically unpacks the map and assigns the values to the corresponding fields of `ambassador`. You can also vary the order of the keys as shown:

```
{ :top-speed 240
  :name "Ambassador" }
```

It still works the same way.

Now, let's retrieve the `:name` and `:top-speed` of `ambassador`:

```
(:name ambassador)
```

Output

```
"Ambassador"
```

```
(get ambassador :name)
```

Output

```
"Ambassador"
```

```
(:top-speed ambassador)
```

Output

```
240
```

```
(get ambassador :top-speed)
```

Output

```
240
```

21.2. Using Records with Functions

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/record_2.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Watch the video for this section here: https://yu7.in/clj-rec-fn

Records can be passed to functions that know how to handle them. Below, we create a record called `Car`.

```
(defrecord Car [name top-speed])
```

Output

```
user.Car
```

We create a variable named `tata-nano`, which is an instance of `Car`:

```
(def tata-nano (->Car "Tata Nano" 120))
```

Output

```
#'user/tata-nano
```

Now, let's write a function that can work with the record; we'll call it `describe`:

```
(defn describe [vehicle]
  (let [{name :name top-speed :top-speed} vehicle]
    (str name " has a top speed of " top-speed "Km/hr.")))
```

Output

```
#'user/describe
```

The `describe` function accepts an argument named `vehicle`. Let's look at the body of the function:

```
(let [{name :name top-speed :top-speed} vehicle]
    (str name " has a top speed of " top-speed "Km/hr."))
```

Here, we are destructuring the `Car` record using `let [{name :name top-speed :top-speed} vehicle]`. In this snippet, the `:name` of the passed `Car` record is assigned to the variable `name`, and `:top-speed` is assigned to `top-speed`. We then return a formatted string that describes the car using `(str name " has a top speed of " top-speed "Km/hr.")`, which embeds the `name` and `top-speed` into the description.

Now, let's use `describe` on an instance of `Car`:

```
(describe tata-nano)
```

Output

```
"Tata Nano has a top speed of 120Km/hr."
```

Now, let's create a new record called `Ship`:

```
(defrecord Ship [name top-speed])
```

Output

```
user.Ship
```

Let's create a new ship instance called `arctic-explorer`:

```
(def arctic-explorer (->Ship "Arctic Explorer" 10))
```

Output

```
#'user/arctic-explorer
```

Let's write a function called `describe-ship` that describes a ship:

```
(defn describe-ship [vehicle]
  (let [{name :name top-speed :top-speed} vehicle]
    (str name " has a top speed of " top-speed " knots.")))
```

Output

```
#'user/describe-ship
```

Let's use `describe-ship` on `arctic-explorer`

```
(describe-ship arctic-explorer)
```

Output

```
"Arctic Explorer has a top speed of 10 knots."
```

It works!

21.3. Protocols

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/protocol.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Watch the video for this section here: https://yu7.in/clj-protocol

In the previous section, we saw how to describe a `Car` using the `describe` function and a `Ship` using the `describe-ship` function. It would be much more convenient if a programmer could use a single `describe` function for both. We will see how to achieve this using protocols.

Let's create a protocol called `Describe` as shown:

```
(defprotocol Describe
```

```
  (describe [this]))
```

Output

```
Describe
```

Let's look at the following code:

```
(defrecord Car [name top-speed]
  Describe
  (describe [this]
    (let [{name :name top-speed :top-speed} this]
      (str name " has a top speed of " top-speed "Km/hr."))))
```

Output

```
user.Car
```

In this example, we create a record called `Car`:

```
(defrecord Car [name top-speed])
```

Next, we include the `Describe` protocol:

```
(defrecord Car [name top-speed]
  Describe)
```

Then, we provide the implementation of the `describe` function for `Car`:

```
(defrecord Car [name top-speed]
  Describe
  (describe [this]
    (let [{name :name top-speed :top-speed} this]
      (str name " has a top speed of " top-speed "Km/hr."))))
```

Note that there is no `defn` here. We simply have the function name `describe`, followed by the argument `this`, and in the body of `describe`, we destructure `this` and return a string description.

The `this` used in the examples in this section is not a special Clojure keyword; it is simply a name given to a variable.

Similarly, for `Ship`, we implement the `describe` function as follows:

```
(defrecord Ship [name top-speed]
  Describe
  (describe [this]
    (let [{name :name top-speed :top-speed} this]
      (str name " has a top speed of " top-speed " knots."))))
```

Output

```
user.Ship
```

Now, let's create an instance of `Car` called `tata-nano`:

```
(def tata-nano (->Car "Tata Nano" 120))
```

Output

```
#'user/tata-nano
```

Next, let's create an instance of `Ship` called `arctic-explorer`:

```
(def arctic-explorer (->Ship "Arctic Explorer" 10))
```

Output

```
#'user/arctic-explorer
```

When we pass `tata-nano` to `describe`, it recognizes that it is of type `Car`, and the `describe` implementation defined within `Car` is called:

```
(describe tata-nano)
```

Output

```
"Tata Nano has a top speed of 120Km/hr."
```

Similarly, it recognizes that `arctic-explorer` is a `Ship`, and `Ship's own `describe` implementation is called in the code below:

```
(describe arctic-explorer)
```

Output

```
"Arctic Explorer has a top speed of 10 knots."
```

21.3.1. Extending Protocols

For this section, you can use the code at https://gitlab.com/clojure-book/code/-/raw/master/extend-protocol.clj. Copy and paste the lines one by one into your REPL, whether the REPL runs in your terminal or is integrated with your IDE.

Watch the video for this section here: https://yu7.in/clj-ext-pcl

We have a protocol called `Describe`:

```
(defprotocol Describe
  (describe [this]))
```

Output

```
Describe
```

We used it to implement the `describe` function for the `Car` record:

```
(defrecord Car [name top-speed]
  Describe
  (describe [this]
    (let [{name :name top-speed :top-speed} this]
      (str name " has a top speed of " top-speed "Km/hr."))))
```

Output

```
user.Car
```

And it works:

```
(def tata-nano (->Car "Tata Nano" 120))
```

Output

```
#'user/tata-nano
```

```
(describe tata-nano)
```

Output

```
"Tata Nano has a top speed of 120Km/hr."
```

Suppose we have code written by someone else that defines a `Rocket` record. We want to extend the `Describe` protocol for it without modifying the original `Rocket` record's code.

```
(defrecord Rocket [name orbit])
```

Output

```
user.Rocket
```

For this purpose, Clojure provides the `extend-protocol` function, which can be used to extend the `Describe` protocol as shown below:

```
(extend-protocol Describe
  Rocket
   (describe [this] (str (:name this) " reaches " (:orbit this) " orbit.")))
```

Output

```
nil
```

In the code above, we specify that we want to extend a protocol using:

```
(extend-protocol)
```

We specify that we want to extend `Describe` by passing it as the first argument:

```
(extend-protocol Describe)
```

As the second argument, we specify that we want to extend the protocol for the `Rocket` record:

```
(extend-protocol Describe
  Rocket)
```

Finally, we define the implementation of the `describe` function:

```
(extend-protocol Describe
  Rocket
   (describe [this] (str (:name this) " reaches " (:orbit this) " orbit.")))
```

Now, let's create a `Rocket` instance called `pslv`:

```
(def pslv (->Rocket "PSLV" "Low Earth"))
```

Output

```
#'user/pslv
```

Now, let's pass it to `describe`:

```
(describe pslv)
```

Output

```
"PSLV reaches Low Earth orbit."
```

It works!

Chapter 22. Namespaces

Get source code here https://gitlab.com/clojure-book/code/-/raw/master/name_space.clj

Watch video for this section here https://yu7.in/clj-ns

The same word can have different meanings depending on the context. For example, 'booking' a hotel means one thing, a 'book' in a library means another, and to 'book' someone in a police station means something else entirely. Similarly, a 'page' in a book is different from a 'page' in an operating system, which is further different from 'Page' as a person's last name.

To resolve such ambiguities in coding, Clojure provides a feature called namespaces. Consider the program `name_space.clj` below; try typing and executing it.

```
;; name_space.clj

(ns lawyer)

(def about-me "I never speak truth.")

(ns politician)

(def about-me "I loot the nation.")

(ns engineer)

(def about-me "I apply science.")

(println lawyer/about-me)
(println politician/about-me)
(println about-me)

(ns politician)

(println about-me)
```

Execute it using `clj` as shown:

```
$ clj name_space.clj
```

Output:

```
I never speak truth.
I loot the nation.
I apply science.
```

```
I loot the nation.
```

Now let's see how the above program works. Look at this code:

```
(ns lawyer)

(def about-me "I never speak truth.")

(ns politician)

(def about-me "I loot the nation.")

(ns engineer)

(def about-me "I apply science.")
```

First, we create a namespace called `lawyer`:

```
(ns lawyer)
```

In it, we define a variable called `about-me` with a specific value:

```
(ns lawyer)

(def about-me "I never speak truth.")
```

Next, we define a namespace called `politician` with its own variable called `about-me`:

```
(ns lawyer)

(def about-me "I never speak truth.")

(ns politician)

(def about-me "I loot the nation.")
```

The `about-me` definition in the `lawyer` namespace is not overwritten by `(def about-me "I loot the nation.")` because they reside in different namespaces; the lawyer still does not speak the truth.

Now we create another namespace called `engineer` and define another `about-me` within that namespace:

```
(ns lawyer)

(def about-me "I never speak truth.")
```

```
(ns politician)

(def about-me "I loot the nation.")

(ns engineer)

(def about-me "I apply science.")
```

Now let's see how to access these three different `about-me` definitions in different namespaces.

We are currently in the `engineer` namespace. To access `about-me` in the `lawyer` namespace, we need to use `lawyer/about-me`, as shown in the last line of the code snippet below:

```
(ns engineer)

(def about-me "I apply science.")

(println lawyer/about-me)
```

This will print `I never speak truth.`. Similarly, look at the last line in the code snippet below:

```
(ns engineer)

(def about-me "I apply science.")

(println lawyer/about-me)
(println politician/about-me)
```

By printing `politician/about-me`, we access the value of `about-me` in the `politician` namespace, resulting in the output `I loot the nation.` on the terminal.

Since we are in the `engineer` namespace, there is no need to use `engineer/about-me`, although doing so would make the code more explicit. Look at the last line in the snippet below:

```
(ns engineer)

(def about-me "I apply science.")

(println lawyer/about-me)
(println politician/about-me)
(println about-me)
```

Since this `about-me` is called within the `engineer` namespace, it prints `I apply science.`.

Finally, let's switch the namespace to `politician` using the following line:

```
(ns politician)
```

Now that we have switched to the `politician` namespace, printing `about-me`:

```
(println about-me)
```

prints `I loot the nation.` once again.

Chapter 23. Exception Handling

Watch video for this section here https://yu7.in/clj-exh

The world is a big and complex place. While you code, you look into a tiny set of precise rules that best describe the problem thrown at you, and there is a chance that the logic you create does not satisfy the world's needs. Something unexpected might happen, and you may need to handle it in your code. Welcome to exception handling.

Let's say you want to read from a file, but the file does not exist. To read a file, we use `(slurp "does_not_exist.txt")`; this will throw an exception because `does_not_exist.txt` does not exist. To handle this, we wrap it and tell Clojure to try it as shown:

```
(try
  (slurp "does_not_exist.txt"))
```

Still, when an exception occurs, we need to capture it. We can use `(catch Exception e (println (str "caught exception: " (.getMessage e))))` as shown below:

```
(try
  (slurp "does_not_exist.txt")
  (catch Exception e (println (str "caught exception: " (.getMessage e)))))
```

Output

```
caught exception: does_not_exist.txt (No such file or directory)
```

When we execute the code above, we get the output shown above. That is, the exception is caught in variable `e`, and we retrieve the message using `(.getMessage e)` and print it out.

Whenever an exception occurs or the code breaks, the subsequent code does not get executed. Execute the code below:

```
(try
  (slurp "does_not_exist.txt")
  (println "this won't be printed")
  (catch Exception e (println (str "caught exception: " (.getMessage e)))))
```

Output

```
caught exception: does_not_exist.txt (No such file or directory)
```

In the above example, since `(slurp "does_not_exist.txt")` throws an exception, the line `(println`

`"this won't be printed")` is not executed. The exception is caught and the message is printed via `(catch Exception e (println (str "caught exception: " (.getMessage e))))`.

Suppose that when an exception occurs, you still need to perform an action—perhaps logging it in a file so that the programmer is aware of it. You can do this using a form that includes the `finally` clause:

```
(try
  (slurp "does_not_exist.txt")
  (println "this won't be printed")
  (catch Exception e (println (str "caught exception: " (.getMessage e))))
  (finally (println "code something that will deal with this exception")))
```

Output

```
caught exception: does_not_exist.txt (No such file or directory)
code something that will deal with this exception
```

The `finally` form is executed even if an exception occurred, which is why we see the string `code something that will deal with this exception` printed out.

Until now, we have caught exceptions using a very general form: `(catch Exception e (println (str "caught exception: " (.getMessage e))))`. However, in real coding situations, it is helpful to catch exceptions in a more specific form. For example, if you are trying to open a file, you should check specifically for a `FileNotFoundException`.

You might wonder where `FileNotFoundException` comes from. You can refer to https://docs.oracle.com/javase/8/docs/api/java/io/package-summary.html and look for the "Exception Summary" section.

Take a look at the code below and execute it:

```
(try
  (slurp "does_not_exist.txt")
  (println "this won't be printed")
  (catch java.io.FileNotFoundException e (println (str "caught exception: "
(.getMessage e))))
  (finally (println "code something that will deal with this exception")))
```

Output

```
caught exception: does_not_exist.txt (No such file or directory)
code something that will deal with this exception
```

Here, instead of using a general `Exception` catch, we use `(catch java.io.FileNotFoundException e`

`(println (str "caught exception: " (.getMessage e))))`, and it works. A good programmer should anticipate what could go wrong in their code and catch specific exceptions to deal with them appropriately.

One can catch multiple exceptions in a `try` block. In the example below, we catch `NumberFormatException`, `NullPointerException`, and a general `Exception` to catch any others that were missed. Let's execute the code:

```
(try
  ;; Code that might throw an exception
  (let [x (Integer/parseInt "not-a-number")]
    (println x))

  (catch NumberFormatException e
    (println "Caught a NumberFormatException:" (.getMessage e)))

  (catch NullPointerException e
    (println "Caught a NullPointerException:" (.getMessage e)))

  (catch Exception e
    (println "Caught a generic exception:" (.getMessage e))))
```

Output

```
Caught a NumberFormatException: For input string: "not-a-number"
```

Therefore, a `NumberFormatException` is thrown because the string `not-a-number` cannot be converted to an integer. Let's try the same code with `NullPointerException` and `Exception` as shown below:

```
(defn print-length [s]
  (println "Length of the string is:" (.length s)))

;; Calling the function with a non-null string
(print-length "Hello, World!") ;; Works fine

;; Calling the function with nil
(print-length nil)

(try
  ;; Code that might throw an exception
  (print-length nil)

  (catch NumberFormatException e
    (println "Caught a NumberFormatException:" (.getMessage e)))

  (catch NullPointerException e
    (println "Caught a NullPointerException:" (.getMessage e)))
```

```
  (catch Exception e
    (println "Caught a generic exception:" (.getMessage e))))
```

Output

```
Caught a NullPointerException: nil
```

When the above code is executed, a `NullPointerException` is thrown because `nil` is passed to the `print-length` function, and hence its length cannot be calculated in `(.length s)`. As a result, this code block:

```
(catch NullPointerException e
    (println "Caught a NullPointerException:" (.getMessage e)))
```

gets triggered, and `Caught a NullPointerException: nil` is printed.

Chapter 24. Testing

Watch the video for this section here: https://yu7.in/clj-test

Testing is an integral part of coding. Suppose you write a piece of code that is used millions of times. If a colleague modifies it and it fails in certain cases, how can they identify those failures? When you write code, you should also write tests for it. This ensures that when someone modifies your code, they can run the corresponding tests to verify that everything still works correctly.

Since tests are written in code, testing is automated. Because computers can run these tests very quickly, it saves a significant amount of time.

A robust test suite allows you to refactor your code with confidence, knowing that the tests will verify that the code still works as expected.

Let's consider the piece of code shown below:

```
;; calc_lib.clj

(defn add [a b]
  (+ a b))

(defn sub [a b]
  (- a b))
```

This code is in a file called `calc_lib.clj` and contains two functions that add and subtract two numbers. Now, let's write tests for it.

First, let's create a Clojure file called `calc_lib_test.clj`. Note that the file we are testing is `calc_lib.clj`, and the corresponding test file is `calc_lib_test.clj`. We simply append `_test` to the filename to indicate it is a test file.

```
;; calc_lib_test.clj
```

From the Clojure test library [1], we will require three functions: `deftest`, which is used to define a test; `testing`, which is used to create a named subspace within `deftest`; and `is`, which is used to assert a condition and print a message if the assertion fails.

Our file now looks like this:

```
;; calc_lib_test.clj

(require '[clojure.test :refer [deftest is testing]])
```

Next, we load `calc_lib.clj`, the file we want to test:

```
;; calc_lib_test.clj

(require '[clojure.test :refer [deftest is testing]])

(load-file "calc_lib.clj")
```

Now, let's define a test function called `calc_lib_test`:

```
;; calc_lib_test.clj

(require '[clojure.test :refer [deftest is testing]])

(load-file "calc_lib.clj")

; nest within `deftest` in source file
(deftest calc_lib_test)
```

As shown above, it is defined using `(deftest calc_lib_test)`. Now, let's add a description for what we are testing, `"calc_lib"`, using `(testing "calc_lib")`:

```
;; calc_lib_test.clj

(require '[clojure.test :refer [deftest is testing]])

(load-file "calc_lib.clj")

; nest within `deftest` in source file
(deftest calc_lib_test
  (testing "calc_lib"))
```

Now, let's first test the `add` function by adding another `testing` block:

```
;; calc_lib_test.clj

(require '[clojure.test :refer [deftest is testing]])

(load-file "calc_lib.clj")

; nest within `deftest` in source file
(deftest calc_lib_test
  (testing "calc_lib"
    (testing "add")))
```

We want to verify that `(add 2 2)` equals `4`:

```
(= 4 (add 2 2))
```

Now, we pass this assertion to the `is` function:

```
(is (= 4 (add 2 2)))
```

Finally, we pass it as the second argument to the `testing` function that describes the "add" test:

```
;; calc_lib_test.clj

(require '[clojure.test :refer [deftest is testing]])

(load-file "calc_lib.clj")

; nest within `deftest` in source file
(deftest calc_lib_test
  (testing "calc_lib"
    (testing "add"
      (is (= 4 (add 2 2))))))
```

Now, let's call `calc_lib_test` to run the test:

```
;; calc_lib_test.clj

(require '[clojure.test :refer [deftest is testing]])

(load-file "calc_lib.clj")

; nest within `deftest` in source file
(deftest calc_lib_test
  (testing "calc_lib"
    (testing "add"
      (is (= 4 (add 2 2))))))

(calc_lib_test)
```

Run the file using `clj`:

```
$ clj calc_lib_test.clj
```

Nothing is printed because the test passes.

Now, change `4` to `5` in the code to simulate a failure:

```
;; calc_lib_test.clj

(require '[clojure.test :refer [deftest is testing]])

(load-file "calc_lib.clj")

; nest within `deftest` in source file
(deftest calc_lib_test
  (testing "calc_lib"
    (testing "add"
      (is (= 5 (add 2 2))))))

(calc_lib_test)
```

Run the file again:

```
$ clj calc_lib_test.clj
WARNING: Implicit use of clojure.main with options is deprecated, use -M

FAIL in (calc_lib_test) (calc_lib_test.clj:11)
calc_lib add
expected: (= 5 (add 2 2))
  actual: (not (= 5 4))
```

As you can see, since the assertion fails, the output indicates that within `calc_lib` and `add`, an assertion failed, showing both the expected and actual results.

The more detailed descriptions you provide in `testing` blocks, the easier it is to identify what went wrong. The line number of the failure is also printed.

```
;; calc_lib_test.clj

(require '[clojure.test :refer [deftest is testing]])

(load-file "calc_lib.clj")

; nest within `deftest` in source file
(deftest calc_lib_test
  (testing "calc_lib"
    (testing "add"
      (is (= 5 (add 2 2)) "adding 2 and 2 should give the correct output"))))

(calc_lib_test)
```

We have added a second argument to the `is` function to describe the test. Let's run the file:

```
$ clj calc_lib_test.clj
```

```
WARNING: Implicit use of clojure.main with options is deprecated, use -M

FAIL in (calc_lib_test) (calc_lib_test.clj:11)
calc_lib add
adding 2 and 2 should give the correct output
expected: (= 5 (add 2 2))
  actual: (not (= 5 4))
```

When a test fails, the description passed to `is` is printed, providing more clues for debugging.

Let's revert to the passing code:

```
;; calc_lib_test.clj

(require '[clojure.test :refer [deftest is testing]])

(load-file "calc_lib.clj")

; nest within `deftest` in source file
(deftest calc_lib_test
  (testing "calc_lib"
    (testing "add"
      (is (= 4 (add 2 2))))))

(calc_lib_test)
```

Now, let's add a second assertion to check if `3` and `4` add up to `7`:

```
;; calc_lib_test.clj

(require '[clojure.test :refer [deftest is testing]])

(load-file "calc_lib.clj")

; nest within `deftest` in source file
(deftest calc_lib_test
  (testing "calc_lib"
    (testing "add"
      (is (= 4 (add 2 2)))
      (is (= 7 (add 3 4))))))

(calc_lib_test)
```

Finally, we can test the `sub` function by adding another `testing` block:

```
;; calc_lib_test.clj

(require '[clojure.test :refer [deftest is testing]])
```

```
(load-file "calc_lib.clj")

; nest within `deftest` in source file
(deftest calc_lib_test
  (testing "calc_lib"
    (testing "add"
      (is (= 4 (add 2 2)))
      (is (= 7 (add 3 4))))
    (testing "sub"
      (is (= 0 (sub -2 -2)))
      (is (= 7 (sub 3 -4))))))

(calc_lib_test)
```

[1] https://clojuredocs.org/clojure.test

Chapter 25. Macros

Get the code for this section here https://gitlab.com/clojure-book/code/-/raw/master/macro.clj

Watch video for this section here https://yu7.in/clj-macros

Lets say you want to add 2 and 3 and you will write it like this:

```
(+ 2 3)
```

Where `+` is a function and `2` and `3` are arguments. But let's say that I am more comfortable writing it as `(2 + 3)` rather than `(+ 2 3)`, how I can do that in Clojure?

When you consider any Clojure code like `(+ 2 3)` it's basically a list, you can verify it in REPL as shown

```
user=> (type '(+ 2 3))
clojure.lang.PersistentList
```

The single quote here `'(+ 2 3)` tells to Clojure that not to execute the list. The basic thing is, any program in Clojure is a list. So even `(2 + 3)` is a list. Now all we need to do is convert `(2 + 3)` to `(+ 2 3)` and let it execute.

So let's imagine we capture `(2 + 3)` in a variable called `a-list`:

```
(def a-list '(2 + 3))
```

We take the first element:

```
(first a-list) ; This gets the 2
```

Then after the first we get the last element:

```
(first a-list) ; This gets the 2
(last a-list)  ; This gets the 3
```

We need to grab the plus sign and put it in front, and we see the plus is in the middle of `a-list` which is `(2 + 3)`, that is the `+` is the second element:

```
(second a-list)
(first a-list) ; This gets the 2
```

```
(last a-list)  ; This gets the 3
```

Now we pack it into a list:

```
(list ; convert (2 + 3) to (+ 2  3)
  (second a-list)
  (first a-list)
  (last a-list))
```

And we say the above thing is a macro named `calculate` which take a single argument called `a-list` as input:

```
(defmacro calculate [a-list]
  (list ; convert (2 + 3) to (+ 2  3)
    (second a-list)
    (first a-list)
    (last a-list)))
```

Now one can try this code:

```
;; macro.clj

(defmacro calculate [a-list]
  (list ; convert (2 + 3) to (+ 2  3)
    (second a-list)
    (first a-list)
    (last a-list)))

(println
  (calculate (2 + 3)))
```

This will give 5 as output.

You can also use `macroexpand` keyword to expand a macro, see the code below:

```
(println
  (macroexpand
    '(calculate (2 + 3))))
```

Will print out:

```
(+ 2 3)
```

That's what macro `calculate` is supposed to do after you give `(2 + 3)` as input.

The entire `macro.clj` code is listed below:

```
;; macro.clj

(defmacro calculate [a-list]
  (list ; convert (2 + 3) to (+ 2  3)
    (second a-list)
    (first a-list)
    (last a-list)))

(println
  (calculate (2 + 3)))

(println
  (macroexpand
    '(calculate (2 + 3))))
```

Run it and you should get output like this:

```
5
(+ 2 3)
```

25.1. Templates

Get the code for this section here https://yu7.in/iD9KAU

Watch video for this section here https://yu7.in/Q39kCj

There is a better way of writing macros, that is using templates. In this section we will see how its done.

You know Clojure has `if` method in it, it can be used as follows:

```
(if (even? 1) "even" "odd")
```

Output

```
odd
```

So if `(even? 1)` is `true` then it will return `"even"` else it will return `"odd"`. That is if the condition is true, the second argument will be returned, else the third will be returned.

Now let's code an `unless` macro, it looks as follows:

```
(defmacro unless [pred then else]
  (list 'if (list 'not pred) then else))
```

As seen above, if the prediction is not true, then it returns the second argument, else it returns the third. It's just the opposite of `if`. Let's execute it:

```
(unless (even? 1) "odd" "even")
```

Output

```
odd
```

Seems to work.

Now what if I say there is a shorter way to write it? Look at the code below:

```
(defmacro unless-templating [pred then else]
  `(if (not ~pred) ~then ~else))
```

```
(unless-templating (even? 1) "odd" "even")
```

Output:

```
odd
```

We execute it and it seems to work. So let's see how to write it.

First we have this `defmacro`, which is used to define a macro:

```
(defmacro)
```

Then we have the macro name, which is `unless-templating`:

```
(defmacro unless-templating)
```

Then we get the arguments, which are `pred` and `then` and `else`:

```
(defmacro unless-templating [pred then else])
```

Now we need to return:

```
(if (not pred) then else)
```

But this should not be executed, it should be built and returned, so we use the back tick ` (which is called quote), and it becomes something like this:

```
(defmacro unless-templating [pred then else]
  `(if (not pred) then else))
```

Now when I try `unless-templating` macro:

```
(unless-templating (even? 1) "odd" "even")
```

Output

```
Syntax error compiling at (.calva/output-window/output.calva-repl:69:1).
No such var: user/pred
```

I get the error above. That's because in my macro definition, I'm treating `pred`, `then`, and `else` as variables, but they're actually macro arguments that need to be inserted into the generated code. In the backtick-quoted expression, I need to unquote these arguments using `~`. So here is the corrected code:

```
(defmacro unless-templating [pred then else]
  `(if (not ~pred) ~then ~else))
```

Now when I try `unless-templating` macro:

```
(unless-templating (even? 1) "odd" "even")
```

Output

```
odd
```

It works!

Chapter 26. Java Power

The code for this section can be obtained here https://yu7.in/YYg1Lt

The video for this section can be watched here https://yu7.in/iWM6PT. I will soon put a dedicated video for this section of this book.

Clojure is a hosted language, which means it neatly wraps around the language it targets. Traditionally, Java is its host. There are other incarnations of Clojure that wrap around JavaScript, Dart, .NET, C++, and so on. This book focuses on Clojure running on the JVM (Java Virtual Machine).

Clojure can use the power of the base language it's hosted upon. In the following pages, we are going to see how we can tap into the power of the vast Java ecosystem from your Clojure code.

First, create a Clojure file named `power_of_java.clj` and add a namespace to it.

```
(ns power-of-java)
```

Now, there is a Java class (built into Java) called `LocalDate` [1]. Let's import it into our Clojure file:

```
(ns power-of-java
  (:import [java.time LocalDate]))
```

Execute the code in the REPL.

Output

```
nil
```

Now let's create an instance of `LocalDate`:

```
(. LocalDate now)
```

Output

```
#object[java.time.LocalDate 0x5a17e7da "2025-08-23"]
```

If you look at the above code, we have a list `()`. To use the class `LocalDate`, we provide it as the first argument to the dot operator: `(. LocalDate)`. Since the `now()` method in `LocalDate` returns the current date, we call it like this: `(. LocalDate now)`.

There is another, more idiomatic way to call it:

```
(LocalDate/now)
```

Output

```
#object[java.time.LocalDate 0xc0d150b "2025-08-23"]
```

Isn't `(LocalDate/now)` much simpler than `(. LocalDate now)`? Let's use this notation from now on.

Now, let's say that I want to create an instance of `LocalDate` for a specific date, such as `2025-07-05`. I can use the `of` method as shown:

```
(. LocalDate (of 2025 7 5))
```

Output

```
#object[java.time.LocalDate 0x4a379f2c "2025-07-05"]
```

In the code above, `2025` is the year, `7` is the month, and `5` is the day. These are passed as arguments to the `of` method. Similarly, if I want to create an instance of `LocalDate` for `2025-07-10`, I can use the `of` method as follows:

```
(. LocalDate (of 2025 7 10))
```

Output

```
#object[java.time.LocalDate 0x1d897344 "2025-07-10"]
```

Instead of the above code, we can use the `of` method like this:

```
(LocalDate/of 2025 7 10)
```

Output

```
#object[java.time.LocalDate 0x4ad9050b "2025-07-10"]
```

Let me define two dates named `start-date` and `end-date`:

```
(def start-date (LocalDate/of 2025 7 5))
(def end-date (LocalDate/of 2025 7 10))
```

`now` and `of` are static class methods. Now, let's say I want to add a day to an instance of `LocalDate`. I can use the `plusDays` method as follows:

```
(.plusDays (LocalDate/now) 1)
```

Output

```
#object[java.time.LocalDate 0x1a3a0c1b "2025-08-24"]
```

`plusDays` acts on an instance of `LocalDate`, so we call it like this: `(.plusDays (LocalDate/now) 1)`. Functions like `plusDays` are called instance methods.

Note how we are using the function `plusDays` directly and not the class `LocalDate`. We are not writing it like this:

```
(LocalDate/plusDays (LocalDate/now) 1)
```

That's because `(LocalDate/now)` returns an instance of `LocalDate`, and Clojure can pull `plusDays` from the `LocalDate` class because it knows the type of the instance.

Now, let me write a function `inc-day` which will increment the date by one day.

```
(defn inc-day [date-time]
  (.plusDays date-time 1))
```

Next, let me generate a lazy sequence of dates using the function `sequence-of-days`.

```
(defn sequence-of-days []
  (iterate inc-day (LocalDate/now)))
```

Time to see if our code works. Let's take a sequence of 7 days.

```
(take 7 (sequence-of-days))
```

Output

```
(
  #object[java.time.LocalDate 0x59a25fd8 "2025-08-23"]
  #object[java.time.LocalDate 0x4829ecb8 "2025-08-24"]
  #object[java.time.LocalDate 0x65649752 "2025-08-25"]
  #object[java.time.LocalDate 0x192a07a6 "2025-08-26"]
  #object[java.time.LocalDate 0x523dd7c4 "2025-08-27"]
  #object[java.time.LocalDate 0x5d374cf0 "2025-08-28"]
```

```
  #object[java.time.LocalDate 0x61883365 "2025-08-29"]
)
```

It works!

Now let's create a function `next-n-days` which will return the next `n` days.

```
(defn next-n-days)
```

It takes an argument `n`:

```
(defn next-n-days [n])
```

And it returns the next `n` days from today:

```
(defn next-n-days [n]
 (take n (sequence-of-days)))
```

If no argument is given:

```
(defn next-n-days
  ([n]
   (take n (sequence-of-days)))
  ([]))
```

It should return the next 7 days:

```
(defn next-n-days
  ([n]
   (take n (sequence-of-days)))
  ([]
   (next-n-days 7)))
```

Let's test it out.

```
(next-n-days)
```

Output

```
(
  #object[java.time.LocalDate 0x5d4edd4c "2025-08-23"]
  #object[java.time.LocalDate 0x7f234335 "2025-08-24"]
  #object[java.time.LocalDate 0x1977020a "2025-08-25"]
```

```
  #object[java.time.LocalDate 0x483e3b96 "2025-08-26"]
  #object[java.time.LocalDate 0x63b13b60 "2025-08-27"]
  #object[java.time.LocalDate 0x66ef6c8 "2025-08-28"]
  #object[java.time.LocalDate 0x27a8c35d "2025-08-29"]
)
```

Now let's generate the next 5 days:

```
(next-n-days 5)
```

Output

```
(
  #object[java.time.LocalDate 0x5d184a50 "2025-08-23"]
  #object[java.time.LocalDate 0x71950d03 "2025-08-24"]
  #object[java.time.LocalDate 0x725327ff "2025-08-25"]
  #object[java.time.LocalDate 0x51dd6fcc "2025-08-26"]
  #object[java.time.LocalDate 0x4e08f56d "2025-08-27"]
)
```

In this section, we have seen how to import a Java class and use its functions in Clojure code. The ability to use the power of the hosted language is a very powerful feature that Clojure exploits. By learning Clojure, you have the power to tap into many tried-and-tested ecosystems (in this book its the Java ecosysyem) that have been perfected over decades.

[1] https://yu7.in/wc68VQ

Chapter 27. Projects With Leiningen

Leiningen is a tool that allows you to create Clojure projects. It helps you maintain dependencies, use external libraries, and bundle your project into a JAR file.

There is also a `deps.edn` way of creating projects; I will write about it once I am more familiar with it.

In this section, let's create a small Leiningen project that wishes us "Hello".

27.1. Creating a Leiningen Project

code for this section can be found in https://yu7.in/mGydAO

Watch video for this section here https://yu7.in/clj-lein-proj

Fire up your terminal. We'll name this project `wish-me`, so let's create the app as shown:

```
$ lein new app wish-me
```

Now you will see a folder named `wish-me`. If you go into it, you will see the following structure:

```
wish-me
├── CHANGELOG.md
├── LICENSE
├── README.md
├── doc
│   └── intro.md
├── pom.xml
├── project.clj
├── resources
├── src
│   └── wish_me
│       └── core.clj
├── target
└── test
    └── wish_me
        └── core_test.clj
```

A Clojure expert would explain what all these files mean. But I don't claim such greatness; I'm just a Clojure learner.

Concentrate on the file `src/wish_me/core.clj`; you will see code as shown:

```
(ns wish-me.core
```

```
  (:gen-class))

(defn -main
  "I don't do a whole lot ... yet."
  [& args]
  (println "Hello, World!"))
```

Now, in the terminal, go into the `wish-me` folder and type:

```
$ lein run
```

You will see this output:

```
Hello, World!
```

If you've guessed correctly, the output came from `(println "Hello, World!")` in `src/wish_me/core.clj`. If you're wondering how `lein run` knew that the `-main` function was in `src/wish_me/core.clj`, look at the `project.clj` file:

`project.clj`

```
(defproject wish-me "0.1.0-SNAPSHOT"
  :description "FIXME: write description"
  :url "http://example.com/FIXME"
  :license {:name "EPL-2.0 OR GPL-2.0-or-later WITH Classpath-exception-2.0"
            :url "https://www.eclipse.org/legal/epl-2.0/"}
  :dependencies [[org.clojure/clojure "1.11.1"]]
  :main ^:skip-aot wish-me.core
  :target-path "target/%s"
  :profiles {:uberjar {:aot :all
                       :jvm-opts ["-Dclojure.compiler.direct-linking=true"]}})
```

The `:main ^:skip-aot wish-me.core` line tells `lein run` where to start executing.

27.2. Printing args

code for this section can be found in https://yu7.in/kkXmN5

Now, let's pass some command-line arguments to `lein run`. Modify the program as follows:

```
(ns wish-me.core
  (:gen-class))

(defn -main
  "I don't do a whole lot ... yet."
```

```
  [& args]
  (println args))
```

To implement the code above, remove `(println "Hello, World!")` from `src/wish_me/core.clj` and replace it with `(println args)`. The variable `args` will contain the command-line arguments passed. Now run:

```
$ lein run Karthik
```

This will print a list containing `"Karthik"` as an element, as shown:

```
(Karthik)
```

27.3. Saying Hello

code for this section can be found in https://yu7.in/qChinL

Instead of printing the arguments, let's wish the person hello if their name is passed. Replace `(println args)` with `(println (str "Hello " (first args) "!"))`, and you will get code as shown:

```
(ns wish-me.core
  (:gen-class))

(defn -main
  "I don't do a whole lot ... yet."
  [& args]
  (println (str "Hello " (first args) "!")))
```

Now run:

```
$ lein run Karthik
```

You should get this output:

```
Hello Karthik!
```

27.4. Decorating Output

code for this section can be found in https://gitlab.com/clojure-book/wish-me/-/tree/decorating-output

You shouldn't have a single file that is so large it comprises the entire project. Instead, divide your

program into multiple files. Now, create a file `src/wish_me/decorator.clj` and add this code:

```
(ns wish-me.decorator)

(defn print-stars []
  (println "************************************"))
```

Now let's include it in `core.clj`

```
(ns wish-me.core
  (:gen-class)
  (:require [wish-me.decorator :as d]))

(defn -main
  "I don't do a whole lot ... yet."
  [& args]
  (d/print-stars)
  (println (str "Hello " (first args) "!"))
  (d/print-stars))
```

In the program above, the line `(:require [wish-me.decorator :as d])` includes the `decorator` namespace as `d`. We then call `(d/print-stars)` before and after the greeting.

Now run:

```
$ lein run Karthik
```

Output

```
************************************
Hello Karthik!
************************************
```

You now have a nice greeting with a decorative star line at the top and bottom. This is how you include other files in your program in a Leiningen project.

27.5. Including External Libraries

code for this section can be found in https://gitlab.com/clojure-book/wish-me/-/tree/external-library

Watch video for this section here https://yu7.in/clj-ext-lib

These days, you rarely code in isolation. Leiningen itself is a tool you downloaded from the internet,

and with it you've created the `wish-me` project. If you look at the `project.clj` file, you'll see something like:

```
:dependencies [[org.clojure/clojure "1.11.1"]]
```

Now add the line `[hiccup "2.0.0-RC2"]` to the dependencies, and it will look like this:

```
:dependencies [[org.clojure/clojure "1.11.1"]
               [hiccup "2.0.0-RC2"]]
```

Your `project.clj` should look like this:

`project.clj`

```
(defproject wish-me "0.1.0-SNAPSHOT"
  :description "FIXME: write description"
  :url "http://example.com/FIXME"
  :license {:name "EPL-2.0 OR GPL-2.0-or-later WITH Classpath-exception-2.0"
            :url "https://www.eclipse.org/legal/epl-2.0/"}
  :dependencies [[org.clojure/clojure "1.11.1"]
                 [hiccup "2.0.0-RC2"]]
  :main ^:skip-aot wish-me.core
  :target-path "target/%s"
  :profiles {:uberjar {:aot :all
                       :jvm-opts ["-Dclojure.compiler.direct-linking=true"]}}
```

Hiccup (https://clojars.org/hiccup) is a library for creating HTML. Now, we'll modify our program so that if you run `lein run Someone --html`, rather than printing `Hello Someone!`, it will create a file called `hello.html` with HTML content that wishes you hello.

Modify the code in `core.clj` as follows:

```
(ns wish-me.core
  (:gen-class)
  (:require [wish-me.decorator :as d]
            [hiccup2.core :as h]))

(defn print-to-console [name]
  (d/print-stars)
  (println (str "Hello " name "!"))
  (d/print-stars))

(defn print-to-html [name]
  (spit "hello.html"
        (h/html [:html
                 [:body
                  [:h1 "Hello " name "!"]]])))
```

```
(defn -main
  "I don't do a whole lot ... yet."
  [& args]
  (if (= "--html" (second args))
    (print-to-html (first args))
    (print-to-console (first args))))
```

Now run:

```
$ lein run Karthik --html
```

You should now see a file named `hello.html`. Open it in your browser, and you will see a page like this:

Hello Karthik!

We've included the Hiccup library and used it to generate a webpage. Thanks to Leiningen, the process is very straightforward.

27.6. Jar

Watch video for this section here https://yu7.in/clj-jar

You can pack your application into one standalone JAR file. Just run:

```
$ lein uberjar
```

You will see two JAR files generated in the `target/default+uberjar` folder:

```
Compiling wish-me.core
Compiling wish-me.decorator
Created /Users/karthik/code/wish-me/target/default+uberjar/wish-me-0.1.0-SNAPSHOT.jar
Created /Users/karthik/code/wish-me/target/default+uberjar/wish-me-0.1.0-SNAPSHOT-
standalone.jar
```

I'm not sure what `wish-me-0.1.0-SNAPSHOT.jar` is, but you can run `wish-me-0.1.0-SNAPSHOT-standalone.jar` as follows:

```
$ java -jar target/default+uberjar/wish-me-0.1.0-SNAPSHOT-standalone.jar Karthik
```

This will print the greeting:

```
************************************
Hello Karthik!
************************************
```

Alternatively, passing the `--html` flag will generate an HTML file:

```
$ java -jar target/default+uberjar/wish-me-0.1.0-SNAPSHOT-standalone.jar Karthik
--html
```

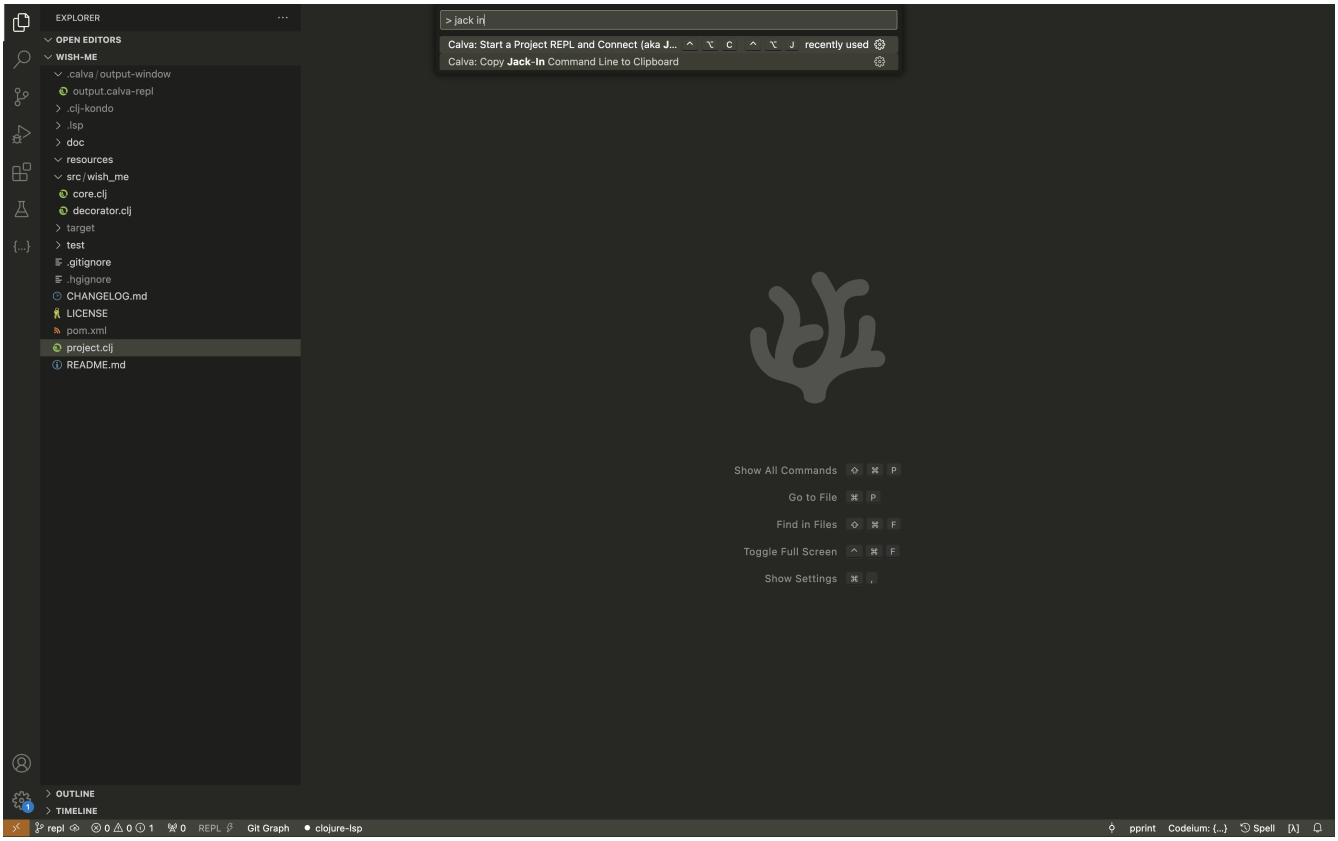
27.7. REPL

Watch video for this section here https://yu7.in/clj-test-lein

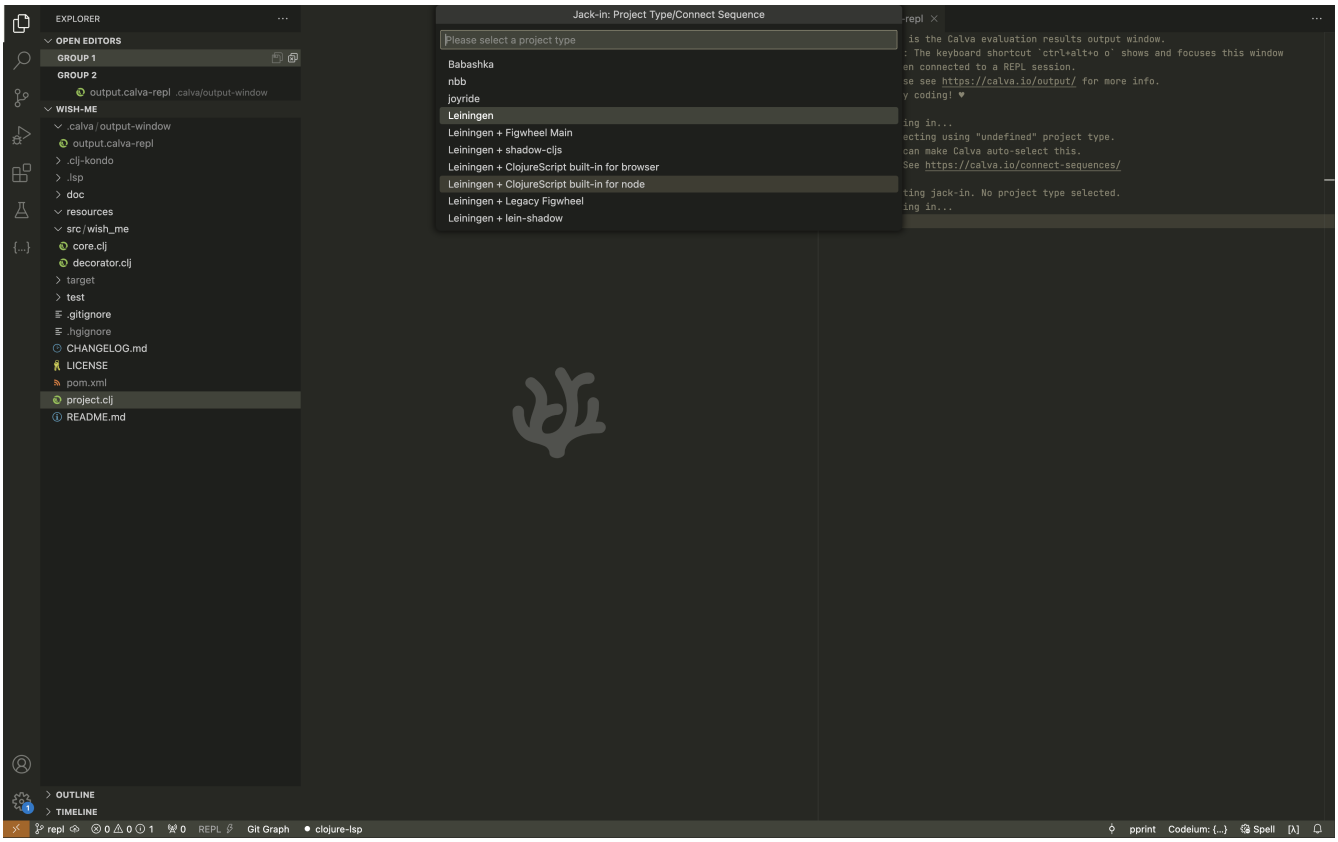
code for this section can be found in https://gitlab.com/clojure-book/wish-me/-/tree/repl

REPL-driven development can significantly accelerate your Clojure development process. In previous sections, you might have used `lein repl` to start a REPL, but since this is now a Leiningen project, things are a bit easier.

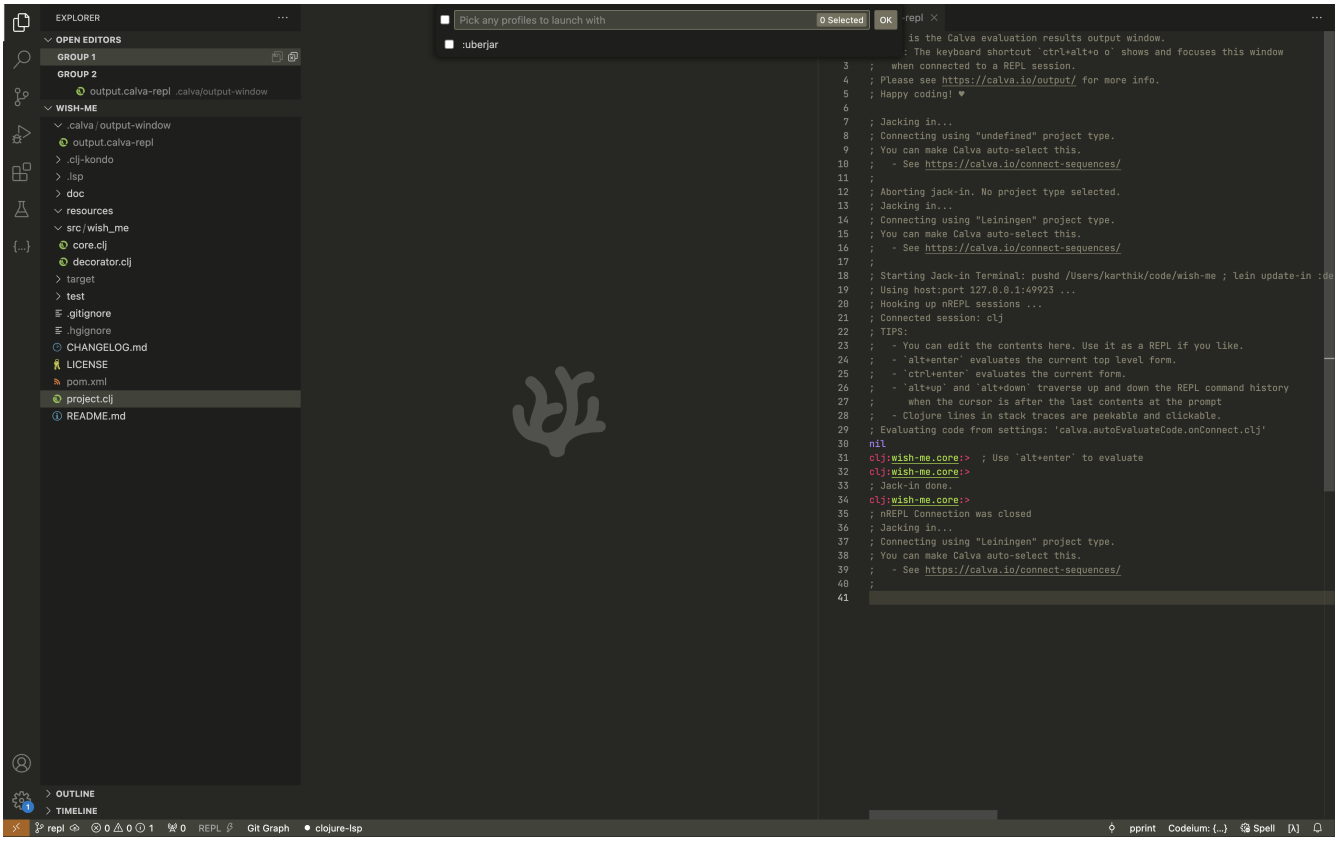
Press `Cmd+P` (Mac) or `Ctrl+P` (Linux/Windows), and type `> jack in` into the prompt:


> jack in
Calva: Start a Project REPL and Connect (aka J... recently used
Calva: Copy Jack-In Command Line to Clipboard
Show All Commands
Go to File
Find in Files
Toggle Full Screen
Show Settings

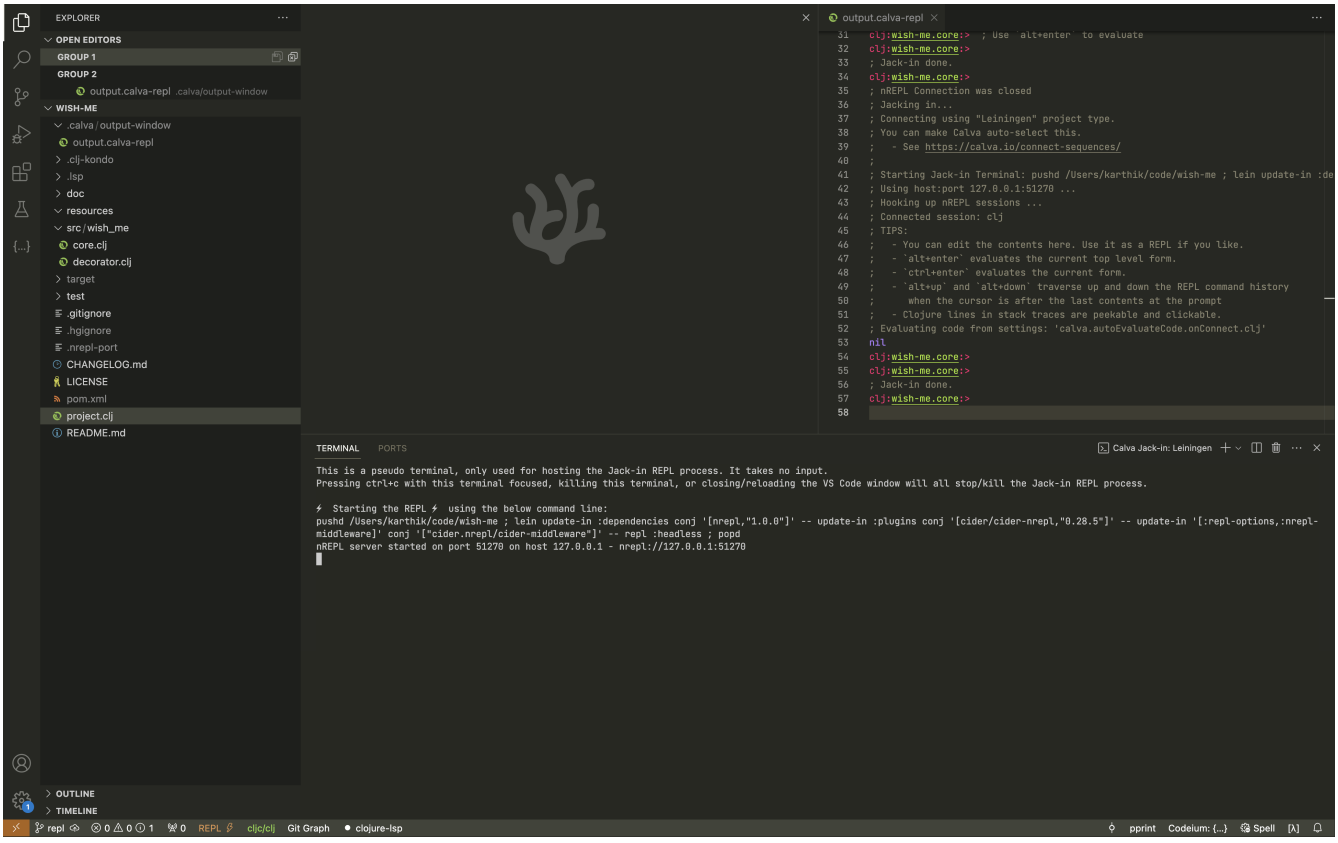
You will see two options: one to "Start a Project REPL" and another to "Copy the jack in command". Select "Start a Project REPL". Next, Calva will present several options; select "Leiningen":



Calva may mention `:uberjar` as shown below; if you're unsure, just press `Enter`.



The REPL will then "jack in" as shown:


EXPLORER
OPEN EDITORS
GROUP 1
GROUP 2
output.calva-repl .calva/output-window
WISH-ME
.calva/output-window
output.calva-repl
.clj-kondo
.lsp
doc
resources
src/wish_me
core.clj
decorator.clj
target
test
.gitignore
.hgignore
.nrepl-port
CHANGELOG.md
LICENSE
pom.xml
project.clj
README.md
OUTLINE
TIMELINE
output.calva-repl
clj:wish-me.core:> ; Use `alt+enter` to evaluate
clj:wish-me.core:>
; Jack-in done.
clj:wish-me.core:>
; nREPL Connection was closed
; Jacking in...
; Connecting using "Leiningen" project type.
; You can make Calva auto-select this.
; - See https://calva.io/connect-sequences/
; Starting Jack-in Terminal: pushd /Users/karthik/code/wish-me ; lein update-in :de
; Using host:port 127.0.0.1:51270 ...
; Hooking up nREPL sessions ...
; Connected session: clj
; TIPS:
; - You can edit the contents here. Use it as a REPL if you like.
; - `alt+enter` evaluates the current top level form.
; - `ctrl+enter` evaluates the current form.
; - `alt+up` and `alt+down` traverse up and down the REPL command history
; when the cursor is after the last contents at the prompt
; - Clojure lines in stack traces are peekable and clickable.
; Evaluating code from settings: 'calva.autoEvaluateCode.onConnect.clj'
nil
clj:wish-me.core:>
clj:wish-me.core:>
; Jack-in done.
clj:wish-me.core:>
TERMINAL
PORTS
Calva Jack-in: Leiningen
This is a pseudo terminal, only used for hosting the Jack-in REPL process. It takes no input.
Pressing ctrl+c with this terminal focused, killing this terminal, or closing/reloading the VS Code window will all stop/kill the Jack-in REPL process.
Starting the REPL using the below command line:
pushd /Users/karthik/code/wish-me ; lein update-in :dependencies conj '[nrepl,"1.0.0"]' -- update-in :plugins conj '[cider/cider-nrepl,"0.28.5"]' -- update-in '[:repl-options,:nrepl-middleware]' conj '["cider.nrepl/cider-middleware"]' -- repl :headless ; popd
nREPL server started on port 51270 on host 127.0.0.1 - nrepl://127.0.0.1:51270
repl 0 0 1 0 REPL cljc/clj Git Graph clojure-lsp
pprint Codeium: {...} Spell

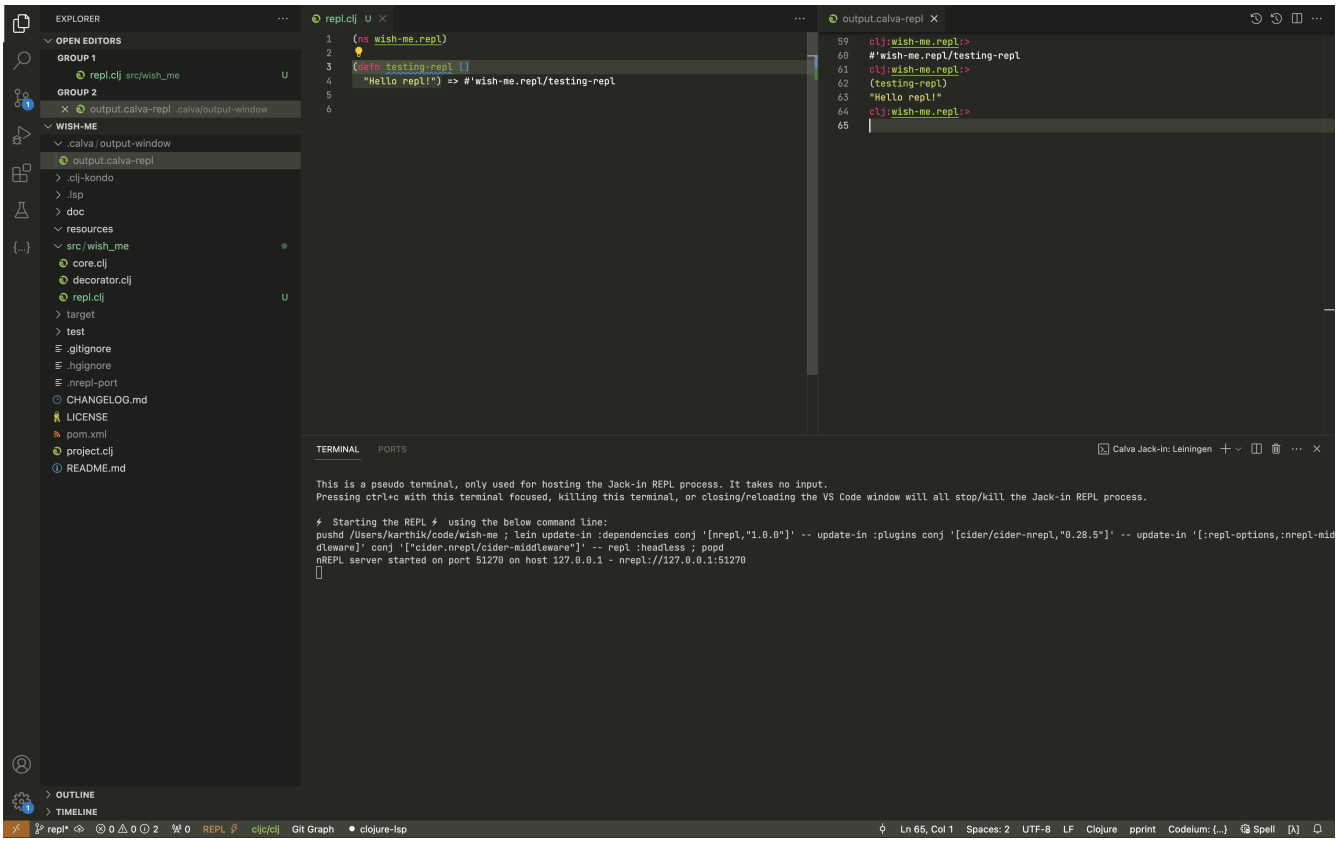
Now, let's create a file named `src/wish_me/repl.clj` and add this code:

`repl.clj`

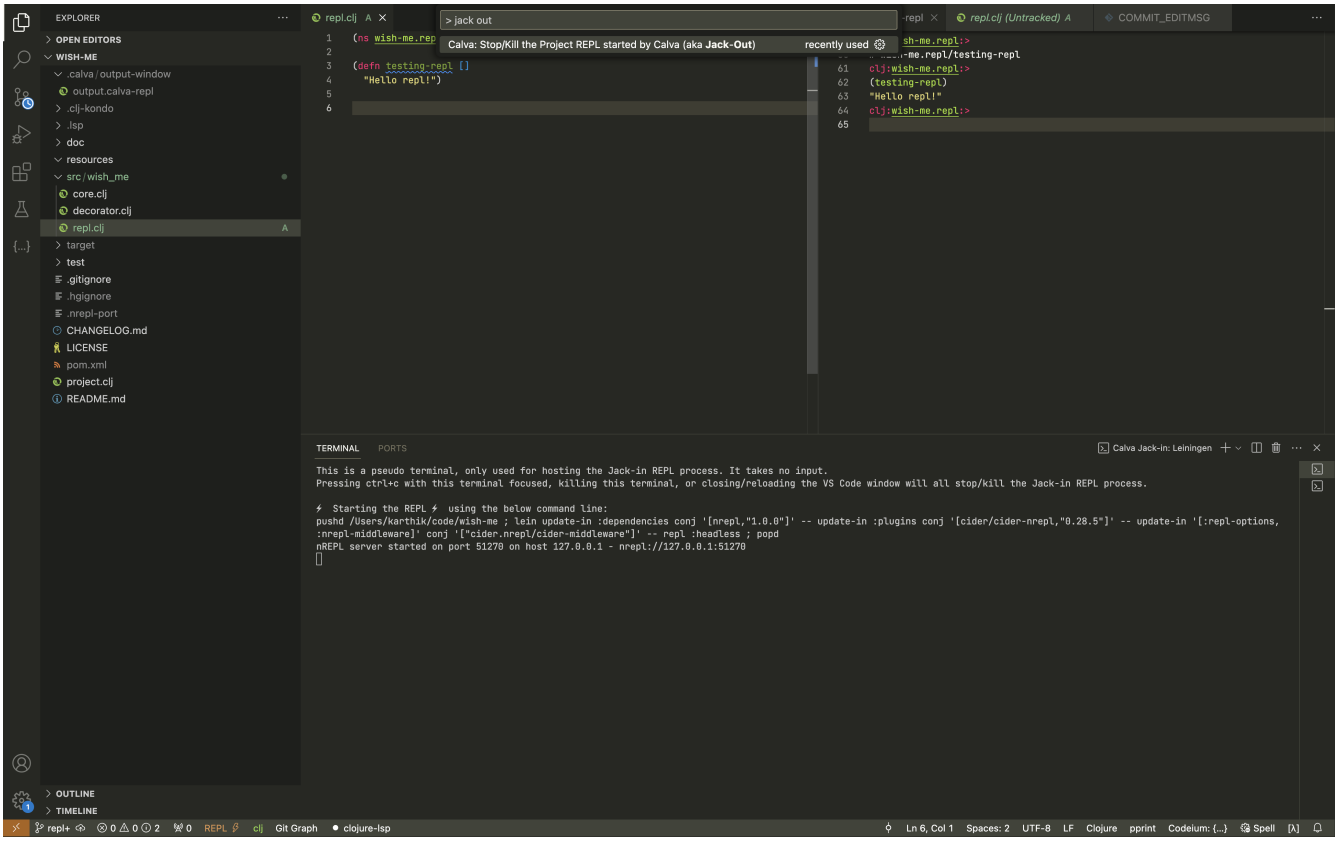
```
(ns wish-me.repl)
```

```
(defn testing-repl []
  "Hello repl!")
```

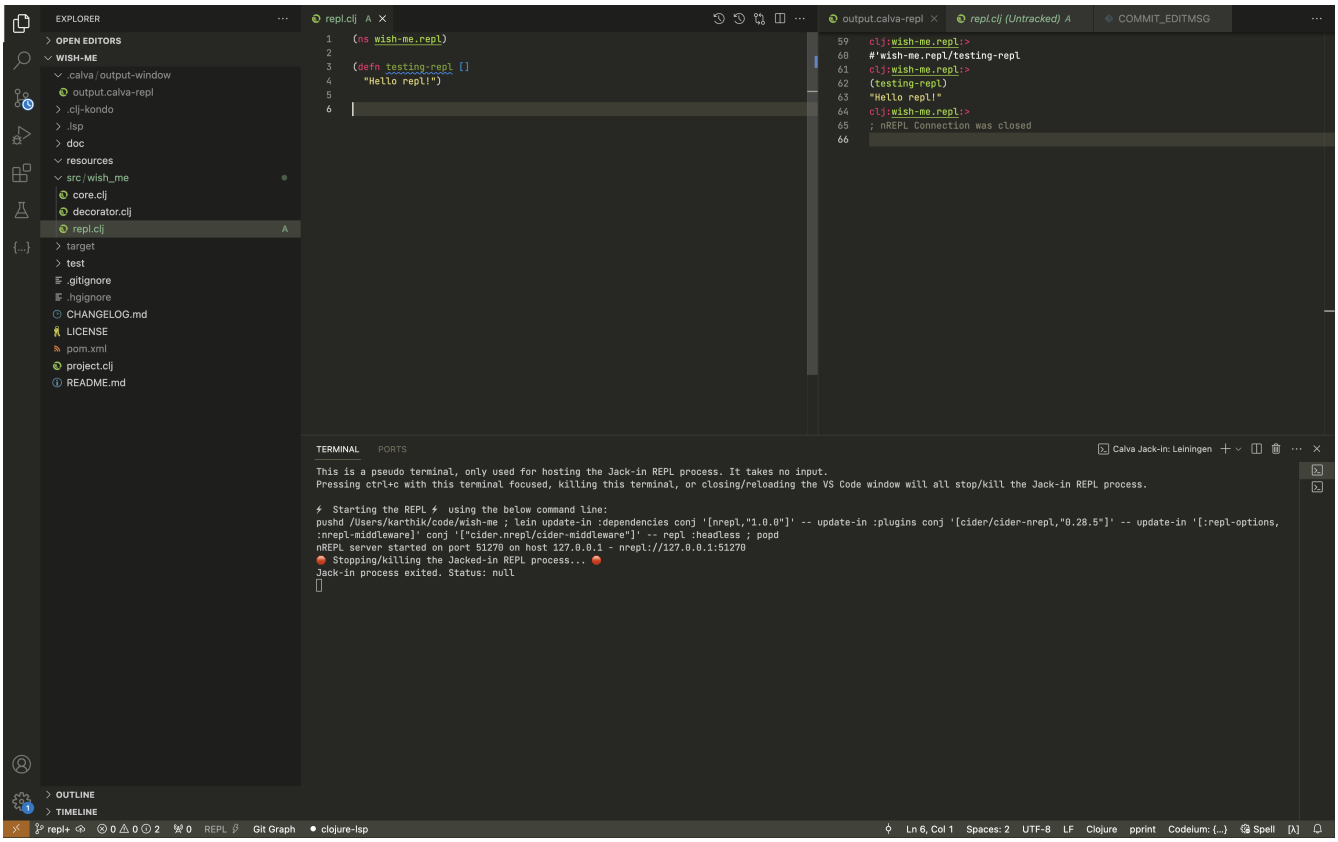
to test the REPL. Place your cursor on `testing-repl` and press `Ctrl` + `Enter` (Linux/Windows) or kbd[Option + Enter] (Mac). You will see the function loaded in the REPL.



Now, in the REPL, call `(testing-repl)`, and you'll see `"Hello repl!"` as the output:


> jack out
Calva: Stop/Kill the Project REPL started by Calva (aka Jack-Out)
recently used
TERMINAL
PORTS
This is a pseudo terminal, only used for hosting the Jack-in REPL process. It takes no input.
Pressing ctrl+c with this terminal focused, killing this terminal, or closing/reloading the VS Code window will all stop/kill the Jack-in REPL process.
Starting the REPL ⚡ using the below command line:
nREPL server started on port 51270 on host 127.0.0.1 - nrepl://127.0.0.1:51270

To stop the REPL, press `Cmd+P` or `Ctrl+P` and type `> jack out` in the prompt. Select the "Jack out" option and the REPL will stop as shown:


TERMINAL
PORTS
This is a pseudo terminal, only used for hosting the Jack-in REPL process. It takes no input.
Pressing ctrl+c with this terminal focused, killing this terminal, or closing/reloading the VS Code window will all stop/kill the Jack-in REPL process.
Starting the REPL ⚡ using the below command line:
nREPL server started on port 51270 on host 127.0.0.1 - nrepl://127.0.0.1:51270
Stopping/killing the Jacked-in REPL process...
Jack-in process exited. Status: null

27.8. Testing

Watch video for this section here https://yu7.in/clj-test-lein

Now, let's test our code by testing the `testing-repl` function in `repl.clj`. This is the code in `src/wish_me/repl.clj`:

`repl.clj`

```
(ns wish-me.repl)

(defn testing-repl []
  "Hello repl!")
```

Create a file at `test/wish_me/repl_test.clj` and add the following code:

`repl_test.clj`

```
(ns wish-me.repl-test
  (:require [clojure.test :refer :all]
            [wish-me.repl :refer :all]))

(deftest testing-repl-test
  (is (= "Hello repl!" (testing-repl))))
```

Let's see what this code does:

```
(ns wish-me.repl-test)
```

This line declares that we are in the `wish-me.repl-test` namespace.

```
(ns wish-me.repl-test
  (:require [clojure.test :refer :all]))
```

The `(:require [clojure.test :refer :all])` line imports all functions from `clojure.test` into the current namespace. To see which functions are available in `clojure.test`, you can visit https://clojuredocs.org/clojure.test/.

Since we're testing `wish-me.repl`, we'll also refer to all functions in that namespace:

```
(ns wish-me.repl-test
  (:require [clojure.test :refer :all]
            [wish-me.repl :refer :all]))
```

Now, let's add a test for `testing-repl` in `repl-test.clj`:

```
(ns wish-me.repl-test
  (:require [clojure.test :refer :all]
            [wish-me.repl :refer :all]))
```

```
(deftest testing-repl-test)
```

The code above defines a test named `testing-repl-test` using the `deftest` macro. `deftest` is defined in `clojure.test` and is used to create test cases.

Now look at the code below:

```
(ns wish-me.repl-test
  (:require [clojure.test :refer :all]
            [wish-me.repl :refer :all]))

(deftest testing-repl-test
  (is (= "Hello repl!" (testing-repl))))
```

We've added `(is (= "Hello repl!" (testing-repl)))` inside the `testing-repl-test` function. The `is` function from `clojure.test` is used to assert that a condition is `true`; you can learn more about it here: https://clojuredocs.org/clojure.test/is/.

We use `(= "Hello repl!" (testing-repl))` to check if `testing-repl` returns `"Hello repl!"`. If it does, the test passes; otherwise, it fails.

Now, let's test it. Run the following command in your terminal:

```
$ lein test :only wish-me.repl-test
```

`lein test` runs the tests in the Leiningen project. To run only the `wish-me.repl-test` namespace, we use the `:only` option:

The output will show that one test and one assertion ran with no failures or errors:

```
lein test wish-me.repl-test

Ran 1 tests containing 1 assertions.
0 failures, 0 errors.
```

To run all tests in the project, run:

```
$ lein test
```

In this case, one test fails. You can examine `core_test.clj` and try to fix the issue.

```
lein test wish-me.core-test

lein test :only wish-me.core-test/a-test
```

```
FAIL in (a-test) (core_test.clj:7)
FIXME, I fail.
expected: (= 0 1)
  actual: (not (= 0 1))

lein test wish-me.repl-test

Ran 2 tests containing 2 assertions.
1 failures, 0 errors.
Subprocess failed (exit code: 1)
```

To run a specific test within a namespace, such as `testing-repl-test`, use the following command:

```
$ lein test :only wish-me.repl-test/testing-repl-test
```

As shown below, the test ran and the assertion passed:

```
lein test wish-me.repl-test

Ran 1 tests containing 1 assertions.
0 failures, 0 errors.
```

Chapter 28. Private Functions

Find the video for this section here: https://yu7.in/private-functions-in-clojure

Get the code for this section here: https://gitlab.com/clojure-book/private_functions

When coding a Clojure namespace, it is not always necessary to expose all its functions to the outside world. It is often enough to expose only the necessary ones. Private functions can be used to reduce complexity and make the code more manageable. We can hide these functions by declaring them as private. In this section, we will see how to define private functions and how to use them.

First, let's create a Leiningen project named `private_functions`.

```
$ lein new private_functions
```

Let's create a file named `src/private_functions/private_and_public_functions.clj` and add the following content:

src/private_functions/private_and_public_functions.clj

```
(ns private-functions.private-and-public-functions)

(defn public-fn []
  "A public function")
```

Now, let's create a file named `src/private_functions/core.clj` and add the following content:

src/private_functions/core.clj

```
(ns private-functions.core
  (:require [private-functions.private-and-public-functions :as f]))

(f/public-fn)
```

Notice that we are requiring the `private-and-public-functions` namespace as `f`. We then call the public function `public-fn` using `(f/public-fn)`. After you jack-in the project and execute `(f/public-fn)`, you should see the following output:

```
"A public function"
```

Now let's add a private function to `private-and-public-functions.clj`. Take a look at the code below:

src/private_functions/private_and_public_functions.clj

```
(ns private-functions.private-and-public-functions)
```

```
(defn public-fn []
  "A public function")

(defn- private-fn []
  "A private function")
```

Notice the use of `defn-` instead of `defn`:

src/private_functions/private_and_public_functions.clj

```
(defn- private-fn []
  "A private function")
```

By using `defn-`, we create a private function. In this case, the function simply returns the string `"A private function"`.

Now let's try to call this private function from `core.clj`:

src/private_functions/core.clj

```
(ns private-functions.core
  (:require [private-functions.private-and-public-functions :as f]))

(f/public-fn)
(f/private-fn) ;; This will not work; you cannot access a private function from
another namespace.
```

As expected, calling `(f/private-fn)` will fail because private functions cannot be accessed from other namespaces.

To allow controlled access to a private function, we can write a public wrapper function called `access-private-fn`:

src/private_functions/private_and_public_functions.clj

```
(ns private-functions.private-and-public-functions)

(defn public-fn []
  "A public function")

(defn- private-fn []
  "A private function")

(defn access-private-fn []
  (private-fn))
```

In the code above, we call `private-fn` inside the public function `access-private-fn`. Now, `access-private-fn` can be called from `core.clj`:

src/private_functions/core.clj

```
(ns private-functions.core
  (:require [private-functions.private-and-public-functions :as f]))

(f/public-fn)
;; (f/private-fn) ;; This still won't work.
(f/access-private-fn)
```

When we execute `(f/access-private-fn)`, we get the following output:

```
"A private function"
```

There is another way to mark a function as private using the `^:private` metadata. Let's examine the following code:

src/private_functions/private_and_public_functions.clj

```
(ns private-functions.private-and-public-functions)

(defn public-fn []
  "A public function")

(defn- private-fn []
  "A private function")

(defn access-private-fn []
  (private-fn))

(defn ^:private another-private-fn []
  "Another private function")

(defn access-another-private-fn []
  (another-private-fn))
```

Notice the metadata:

src/private_functions/private_and_public_functions.clj

```
(defn ^:private another-private-fn []
  "Another private function")
```

Here, `another-private-fn` is marked as private using `^:private`. We can then call `another-private-fn` from within the same namespace using `access-another-private-fn`:

src/private_functions/private_and_public_functions.clj

```
(ns private-functions.private-and-public-functions)
```

```
.....

(defn ^:private another-private-fn []
  "Another private function")

(defn access-another-private-fn []
  (another-private-fn))
```

Now, `access-another-private-fn` can be accessed in `core.clj`:

src/private_functions/core.clj

```
(ns private-functions.core
  (:require [private-functions.private-and-public-functions :as f]))

(f/public-fn)
;; (f/private-fn) ;; Won't work.
(f/access-private-fn)
(f/access-another-private-fn)
```

When `(f/access-another-private-fn)` is executed, the output will be:

```
"Another private function"
```

28.1. Testing Private Functions

To test a private function, we can use a special syntax to access it. Let's create a file named `test/private_functions/private_and_public_functions_test.clj` and add the following content:

test/private_functions/private_and_public_functions_test.clj

```
(ns private-functions.private-and-public-functions-test
  (:require [clojure.test :refer :all]
            [private-functions.private-and-public-functions :as f]))

(deftest private-fn-test
   (testing "A private function"
     (let [fun #'f/private-fn]
       (is (= (fun) "A private function")))))
```

In the code above, `[clojure.test :refer :all]` makes all functions from the `clojure.test` library available, such as `deftest`, `is`, and `testing`. We also require the `private-functions.private-and-public-functions` namespace as `f`.

Let's break down the test. First, we define the test using `deftest` and give it a name, `private-fn-test`:

test/private_functions/private_and_public_functions_test.clj

```
(deftest private-fn-test)
```

Next, we add a description using `testing`:

test/private_functions/private_and_public_functions_test.clj

```
(deftest private-fn-test
   (testing "A private function"))
```

Then, we define a variable called `fun` and assign it the function `f/private-fn` using `let`. Pay close attention to the assignment:

test/private_functions/private_and_public_functions_test.clj

```
(deftest private-fn-test
   (testing "A private function"
     (let [fun #'f/private-fn])))
```

The `#'` symbol before `f/private-fn` is the "var" syntax, which allows us to access the function regardless of its privacy status. We assign this to the variable `fun`, which we can then use to call the function:

test/private_functions/private_and_public_functions_test.clj

```
(deftest private-fn-test
   (testing "A private function"
     (let [fun #'f/private-fn]
       (is (= (fun) "A private function")))))
```

The line `(is (= (fun) "A private function"))` calls the function `fun` and asserts that it returns the expected string `"A private function"`.

Now, let's run the test:

```
$ lein test
```

The output will indicate that the tests have passed:

```
lein test

Ran 1 tests containing 1 assertions.
0 failures, 0 errors.
```

Chapter 29. Debugging in Leiningen project with Calva and nREPL

Official Calva debugger documentation https://calva.io/debugger/

Code for this section can be found here https://gitlab.com/clojure-book/projects/dbg_and_break

There is an excellent library called nREPL that allows you to debug Clojure code step-by-step, set up breakpoints, and inspect values, enabling you to better understand the code execution.

To get started, let's create a Leiningen project called `dbg_and_break`.

```
$ lein new dbg_and_break
```

Now, move into the project directory:

```
$ cd dbg_and_break
```

Open `project.clj`, and you should see something like this:

```
(defproject dbg_and_break "0.1.0-SNAPSHOT"
  :description "FIXME: write description"
  :url "http://example.com/FIXME"
  :license {:name "EPL-2.0 OR GPL-2.0-or-later WITH Classpath-exception-2.0"
            :url "https://www.eclipse.org/legal/epl-2.0/"}
  :dependencies [[org.clojure/clojure "1.12.4"]]
  :repl-options {:init-ns dbg-and-break.core})
```

Take a look at the dependencies:

```
:dependencies [[org.clojure/clojure "1.12.4"]]
```

Let's add the wonderful `nREPL` library. The dependencies should now look like this:

```
:dependencies [[org.clojure/clojure "1.12.4"]
               [nrepl "1.7.0"]]
```

Your `project.clj` should now look like this:

project.clj

```
(defproject dbg_and_break "0.1.0-SNAPSHOT"
  :description "FIXME: write description"
  :url "http://example.com/FIXME"
  :license {:name "EPL-2.0 OR GPL-2.0-or-later WITH Classpath-exception-2.0"
            :url "https://www.eclipse.org/legal/epl-2.0/"}
  :dependencies [[org.clojure/clojure "1.12.4"]
                 [nrepl "1.7.0"]]
  :repl-options {:init-ns dbg-and-break.core})
```

Create a file called `src/dbg_and_break/loop.clj` and add the following code to it:

src/dbg_and_break/loop.clj

```
(ns dbg-and-break.loop)

(loop [i 1]
  (when (<= i 5)
    (println i)
    (recur (inc i))))
```

Jack in and run the code; you should see output like this:

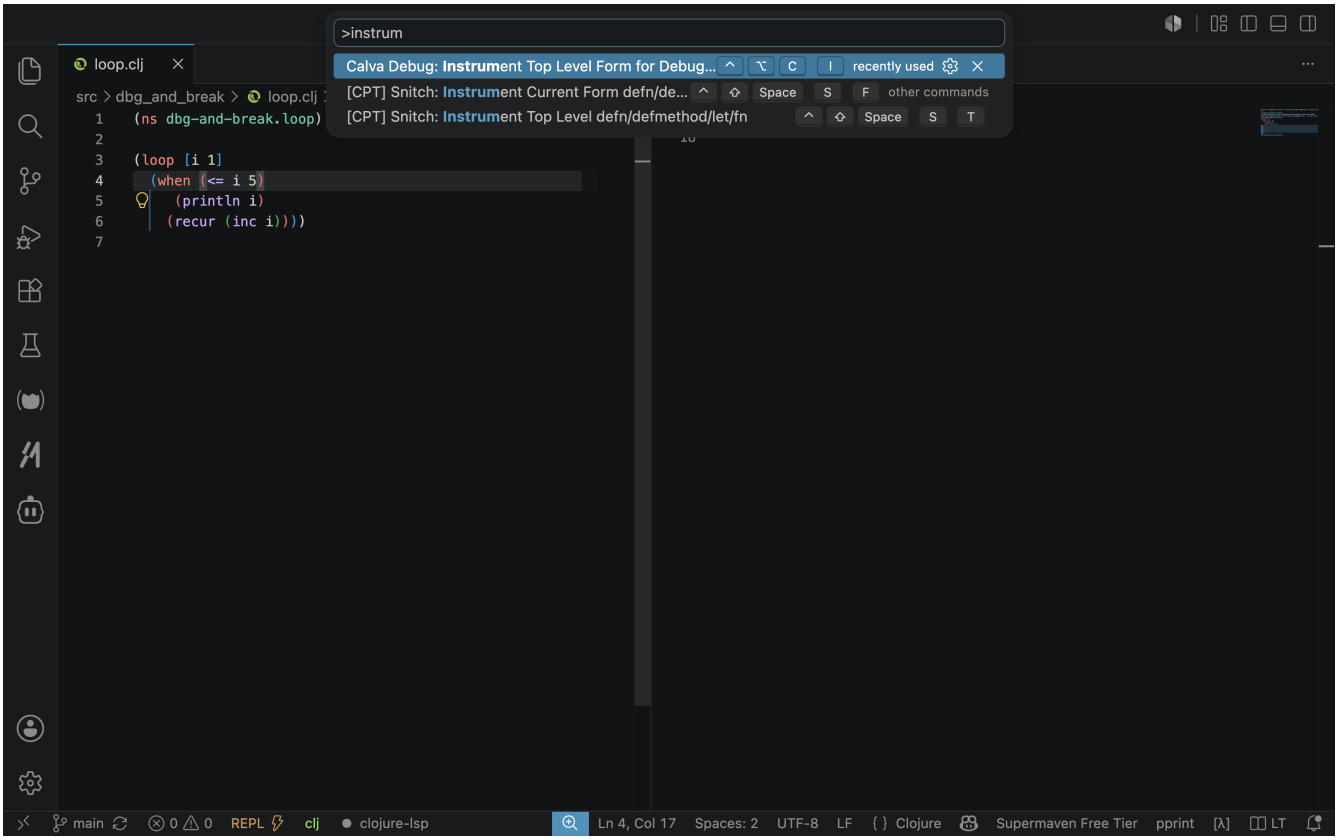
Output

```
; 1
; 2
; 3
; 4
; 5
nil
```

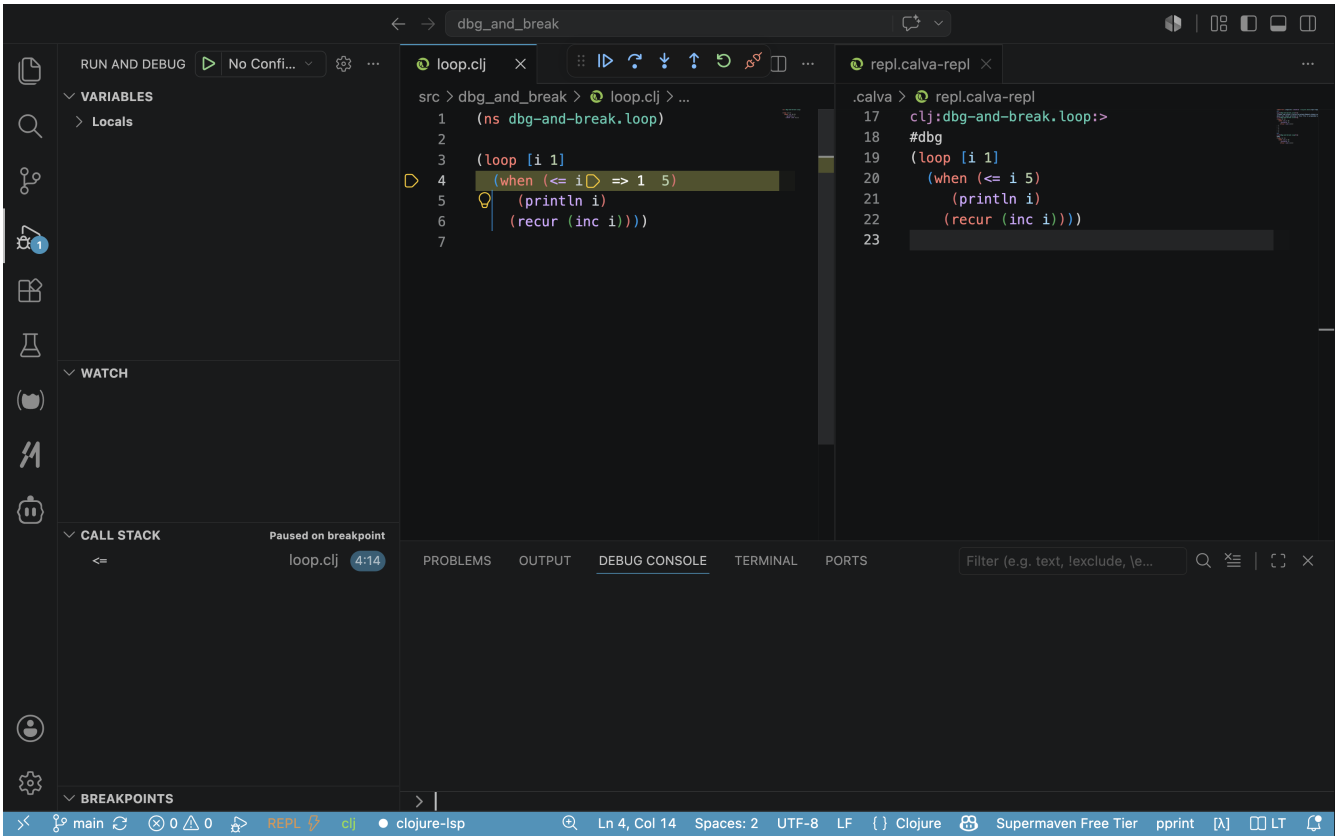
If everything is working correctly, we can proceed.

29.1. #dbg

In VS Code, press `ctrl`+`shift`+`p` or `command`+`shift`+`p`, or type `>` in the top search bar and then type `instrument`. You will see an option like this:

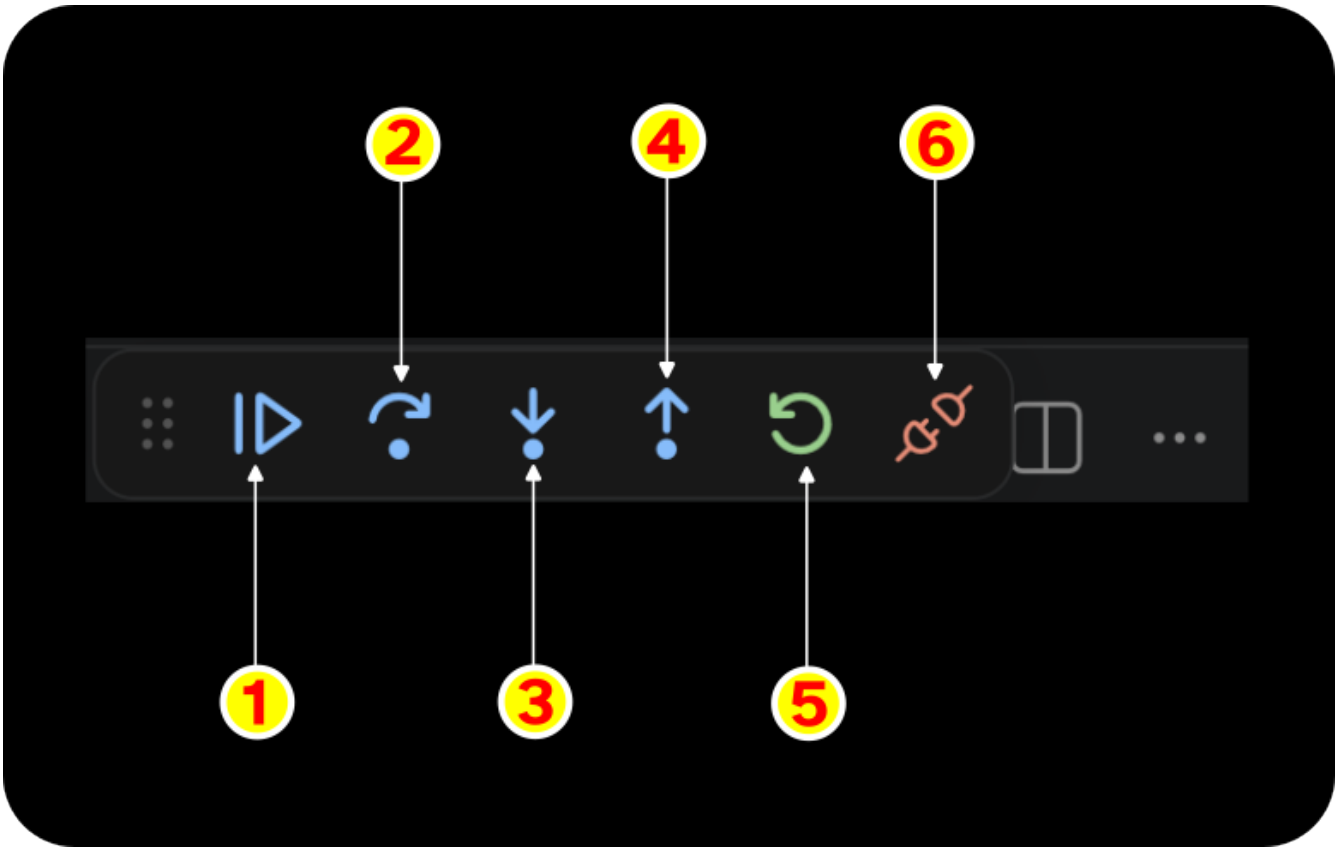


Select **Instrument Top Level Form for Debug**. Note on the right side of the image below, your code now appears with `#dbg` at the top. This `#dbg` tells the `nREPL` library added in `project.clj` that you are in debug mode. This process is called instrumentation.



At the top of your editor, you should see the following debugger controls:

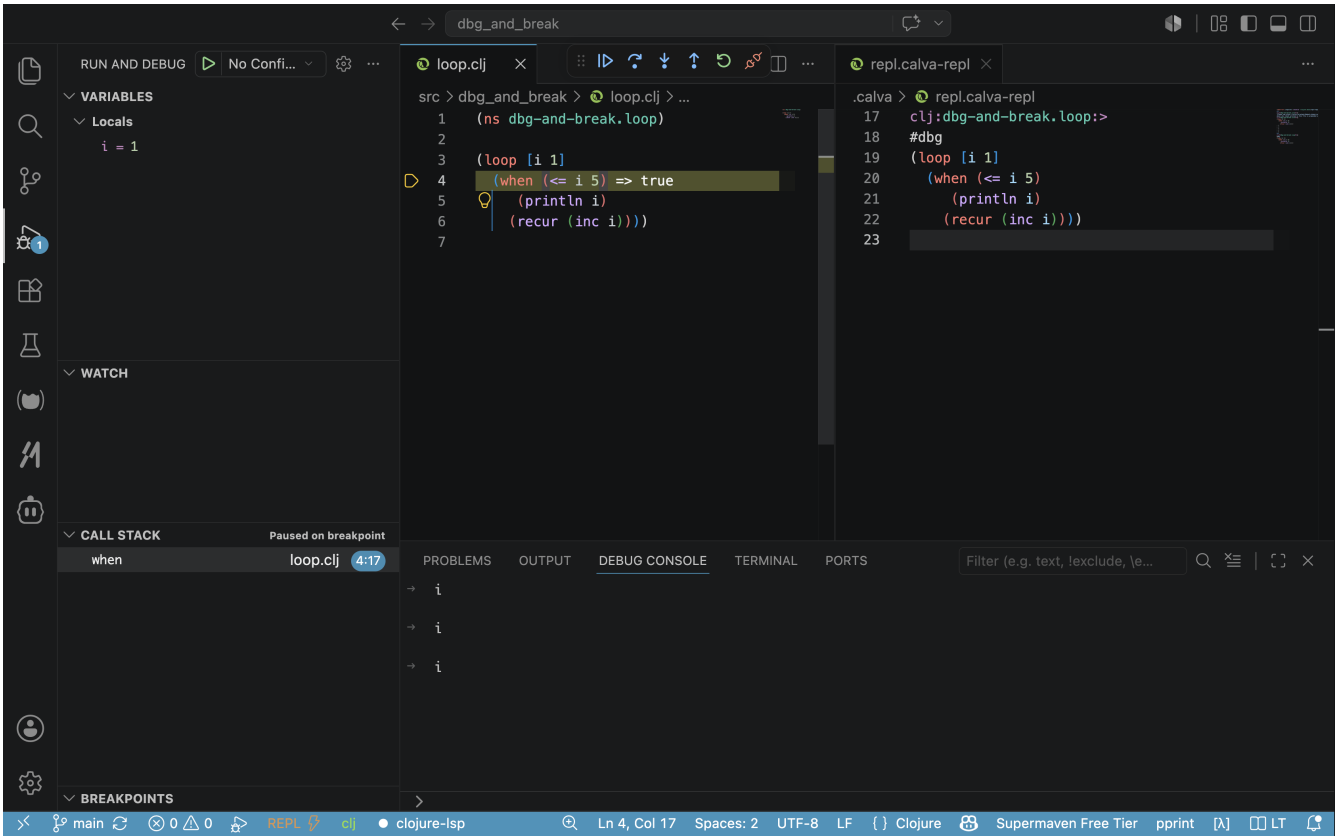
The buttons are as follows:



1. Continue
2. Step Over
3. Step Into
4. Step Out
5. Restart
6. Disconnect

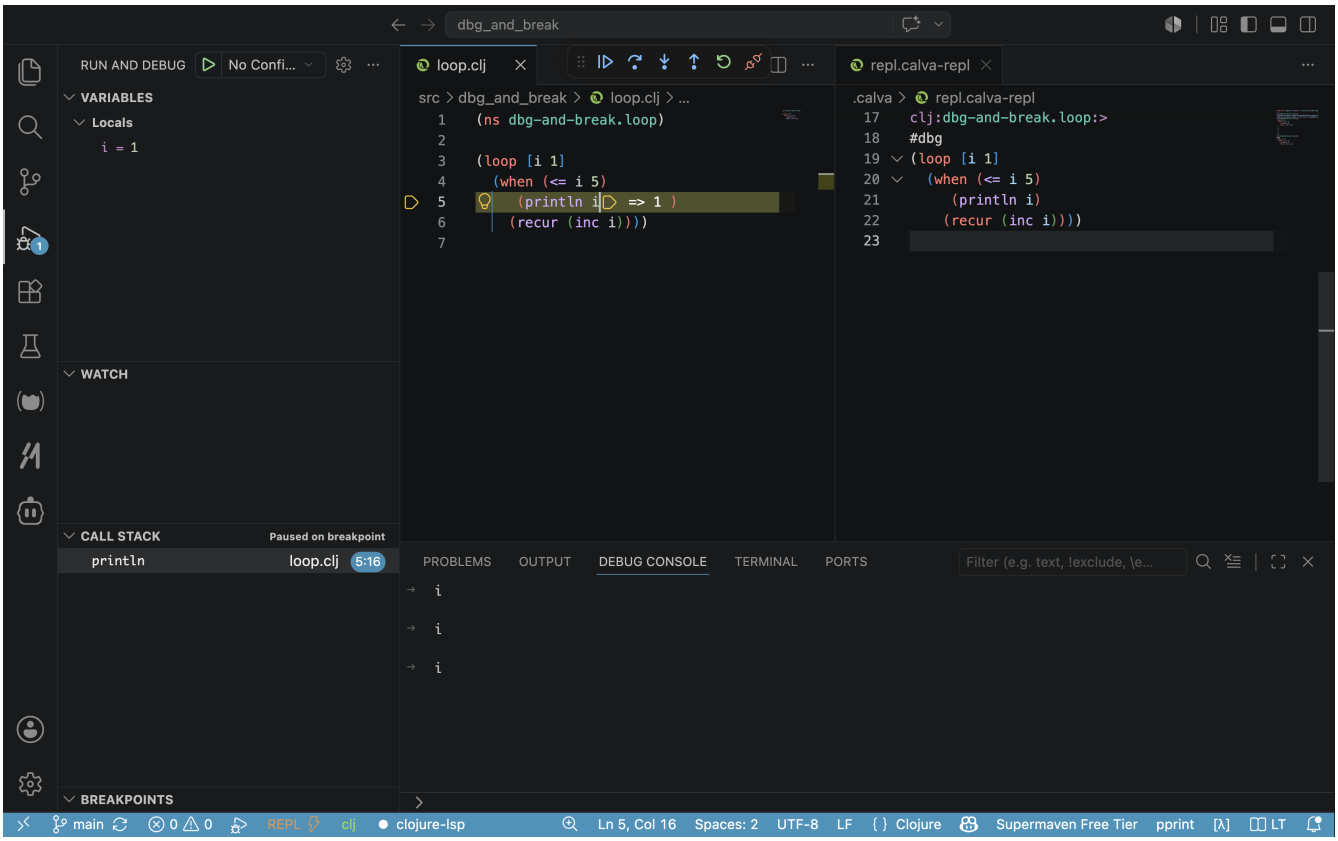
I will focus on the three buttons that are most commonly used here.

As soon as you instrument the form, the `(loop ⋯)` starts running and pauses at the `(when (⇐ i 5))` condition, as shown below:



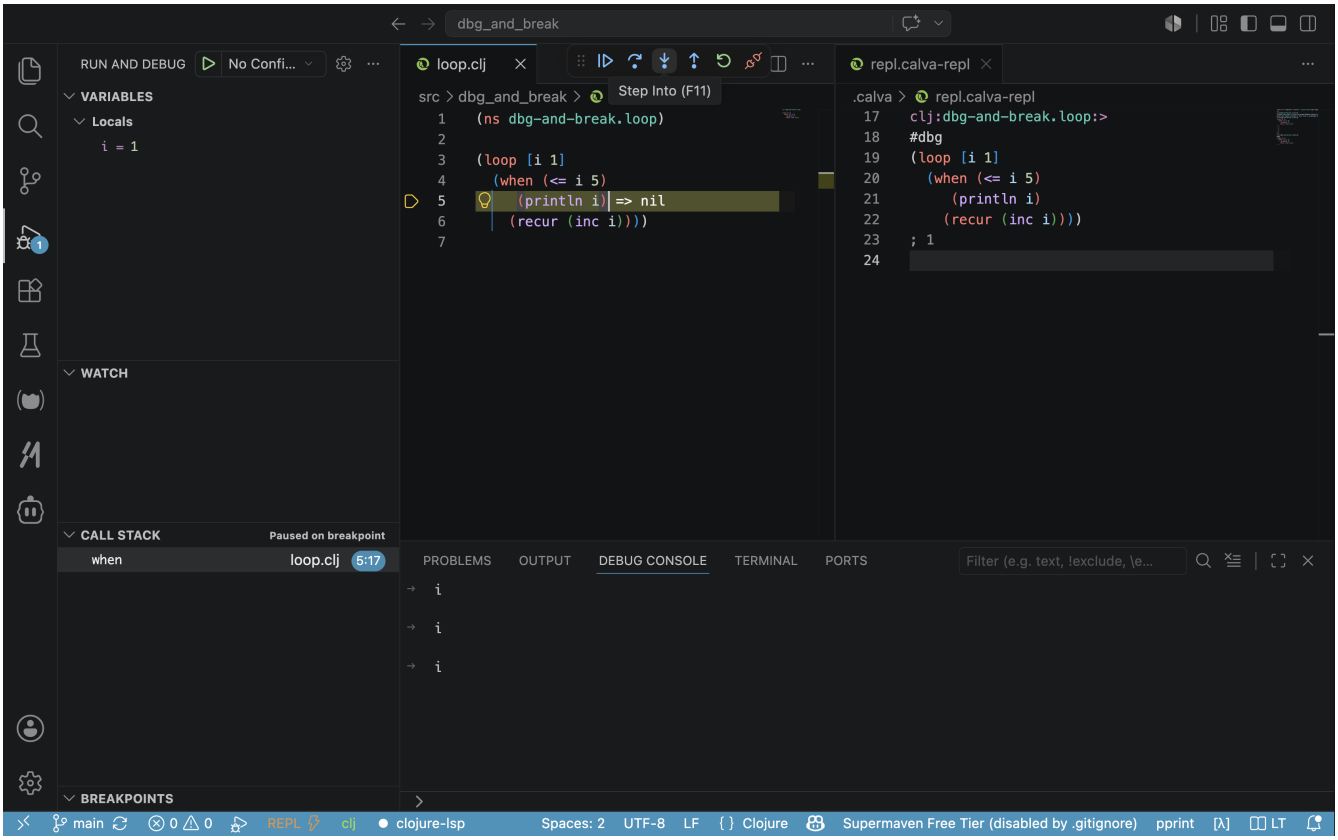
You can see that the debugger indicates `(<= i 5)` returns `true` in your editor. On the left, Calva shows that the current value of `i` is `1`. This provides a very rich debugging experience.

Now hit the **Step Into** button (the one with the downward arrow). You should see the following:

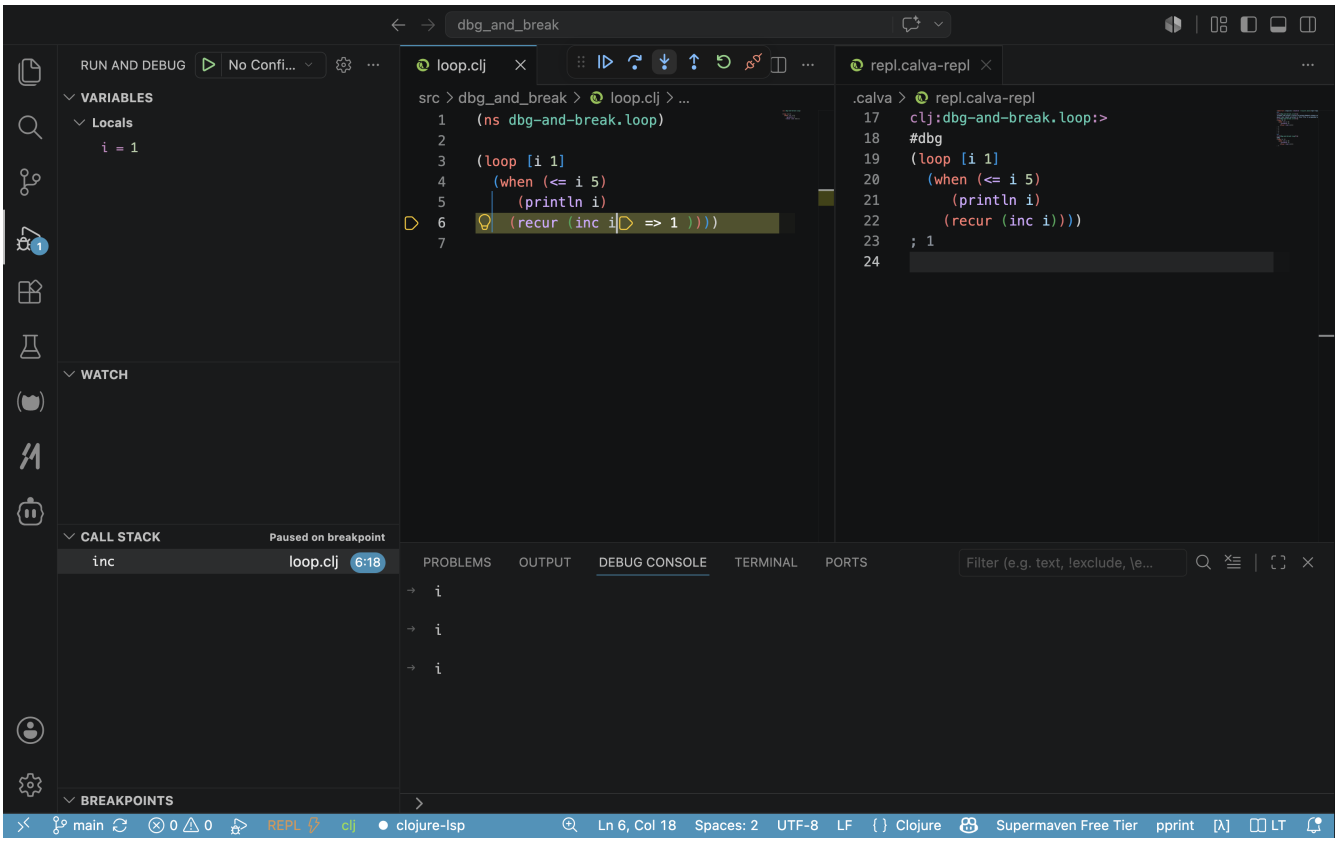


As seen in the image above, the value of `i` is still 1, but the debugger has stopped at the `(println i)` line. Press **Step Into** again; you will see that `println` has returned `nil`, and the value of `i` is printed

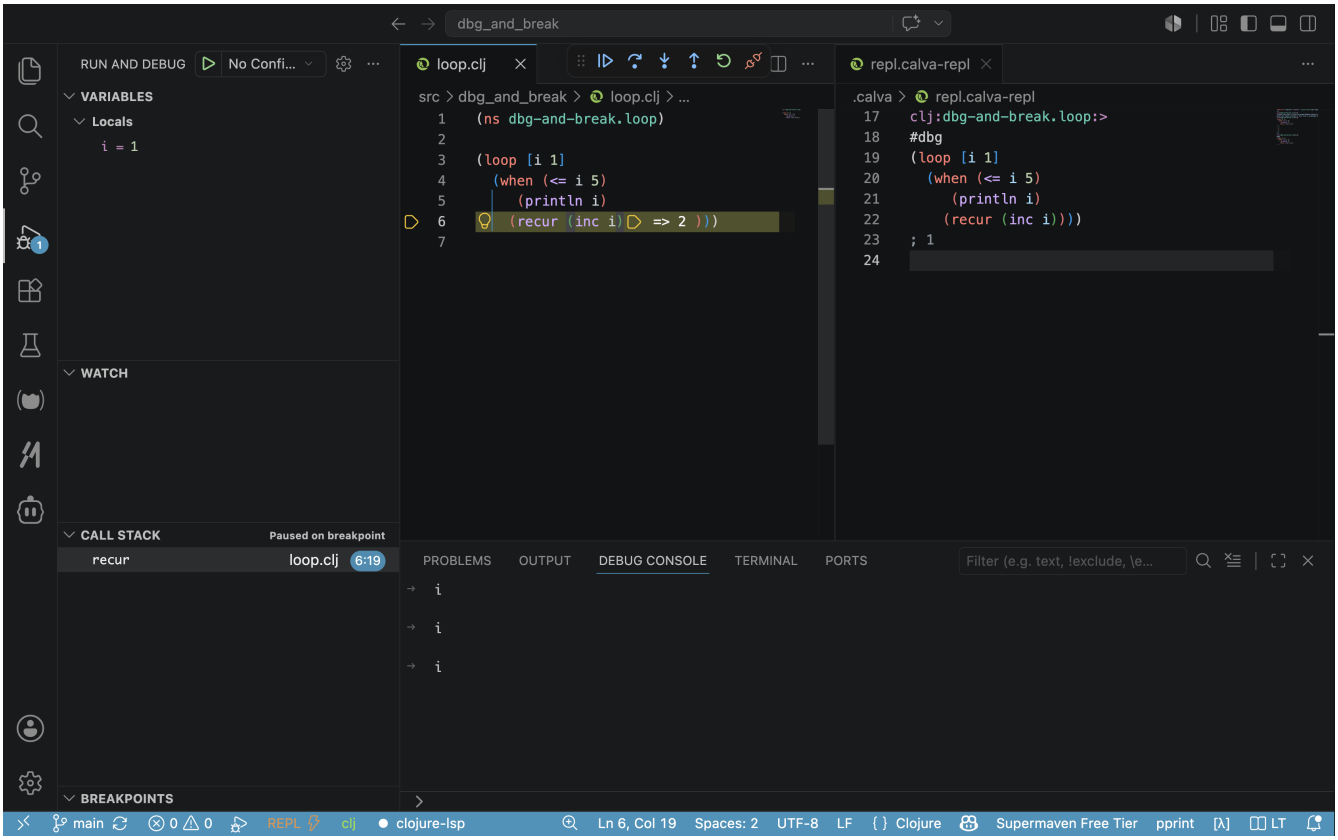
in the Calva REPL output at the right side (see the image below).



Press **Step Into** again, and the debugger will stop at the `(recur (inc i))` line, with `i` still being `1`.

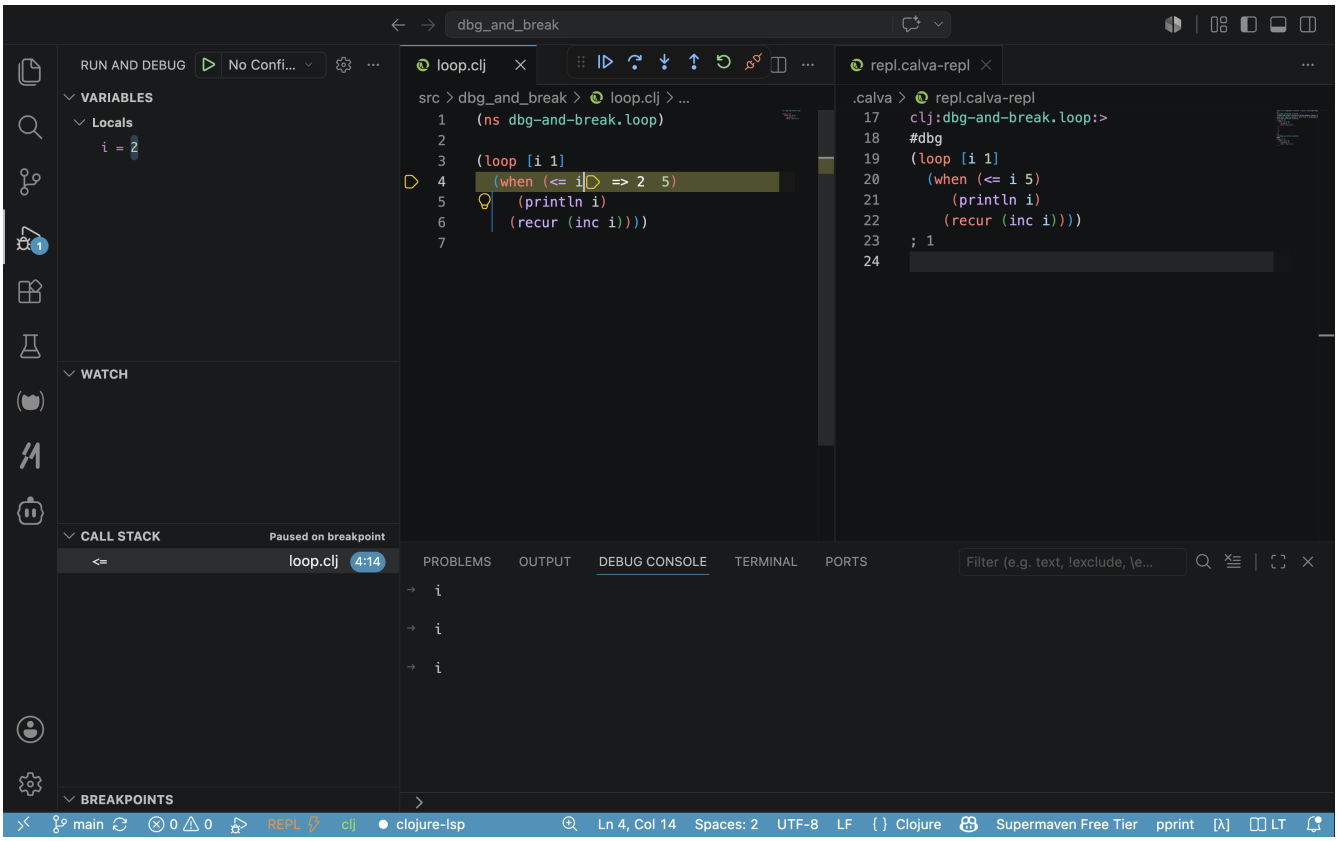


Press **Step Into** once more, and you will see that `(inc i)` returns `2`, and the value of `i` becomes `2`, as shown below:

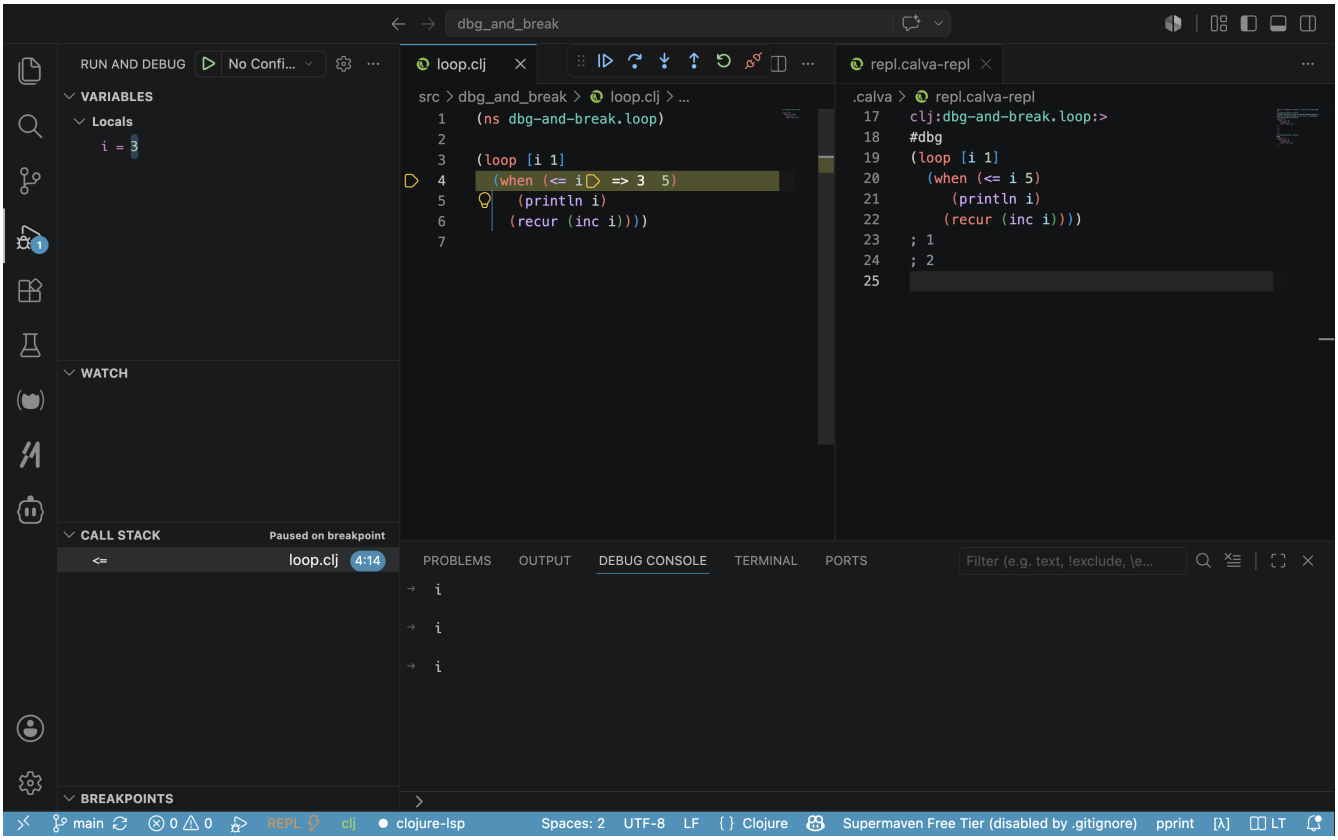


Press **Step Into** again, and after `recur` is executed, the program stops back at the `(when (<= i 5))` line, and the value of `i` is now `2`.

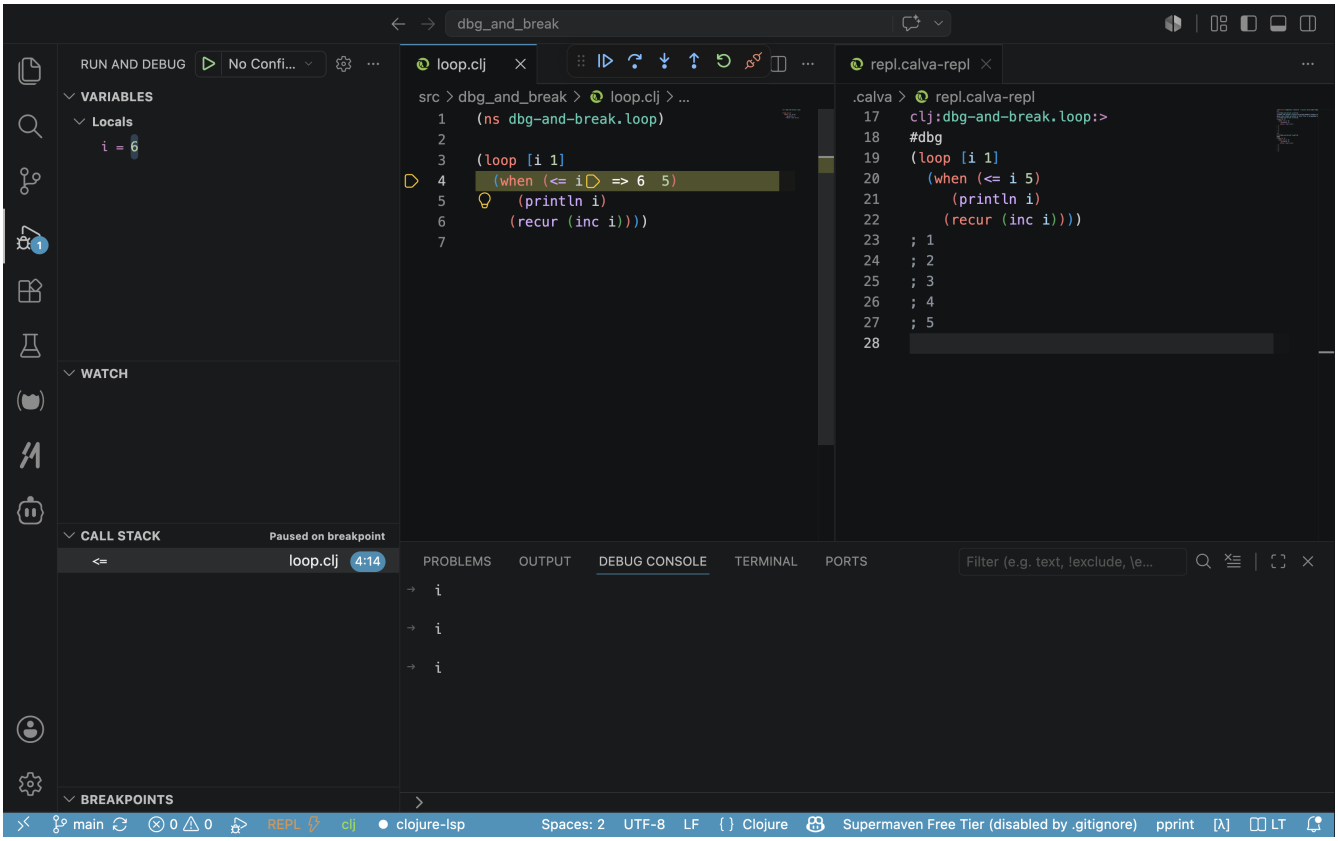
This is how you can step through your code to understand the data flow and debug your logic.



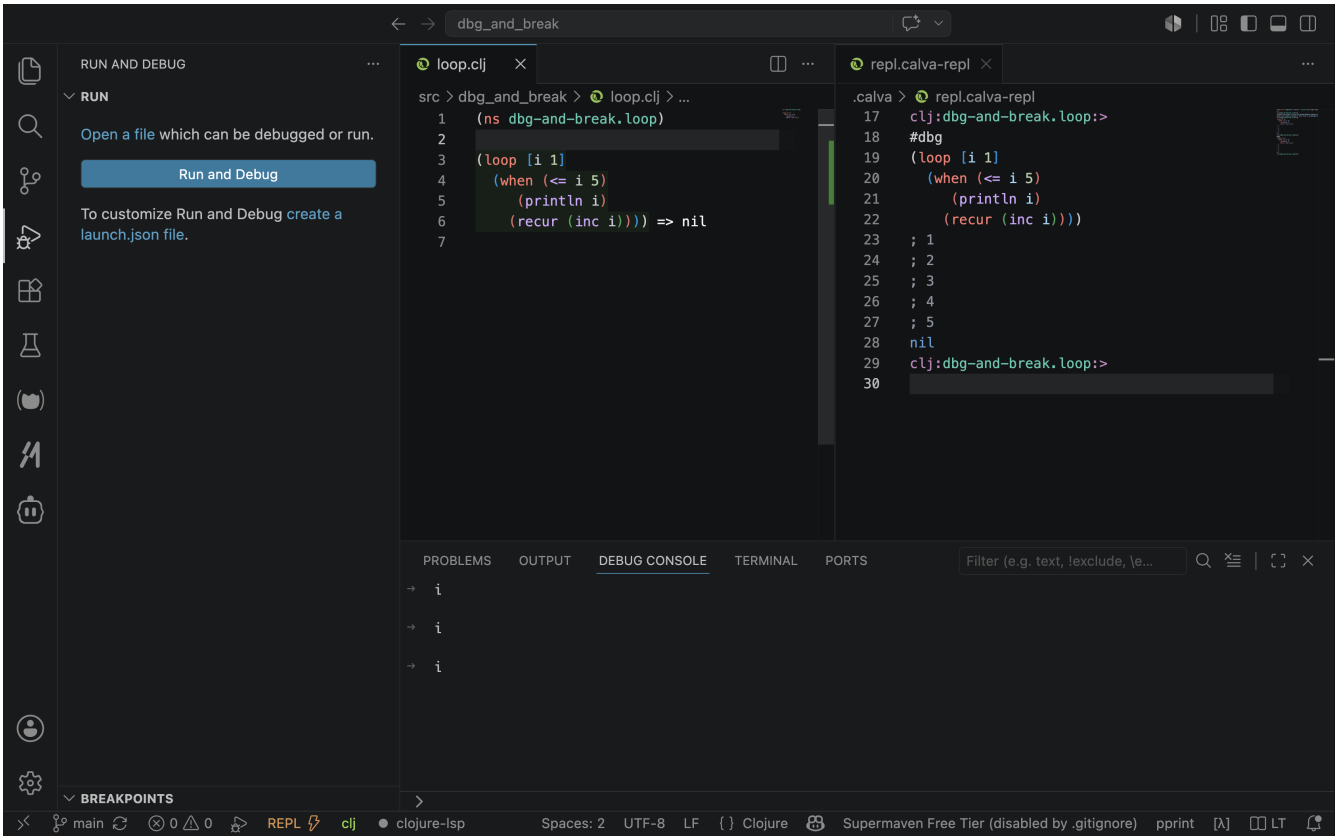
Instead of pressing **Step Into**, you can press the **Continue** button. The program will then stop at the `(when (<= i 5))` line again, and the value of `i` will be `3`.



Continue pressing the **Continue** button until the program stops at the `(when (⇐ i 5))` line and the value of `i` reaches `6`.



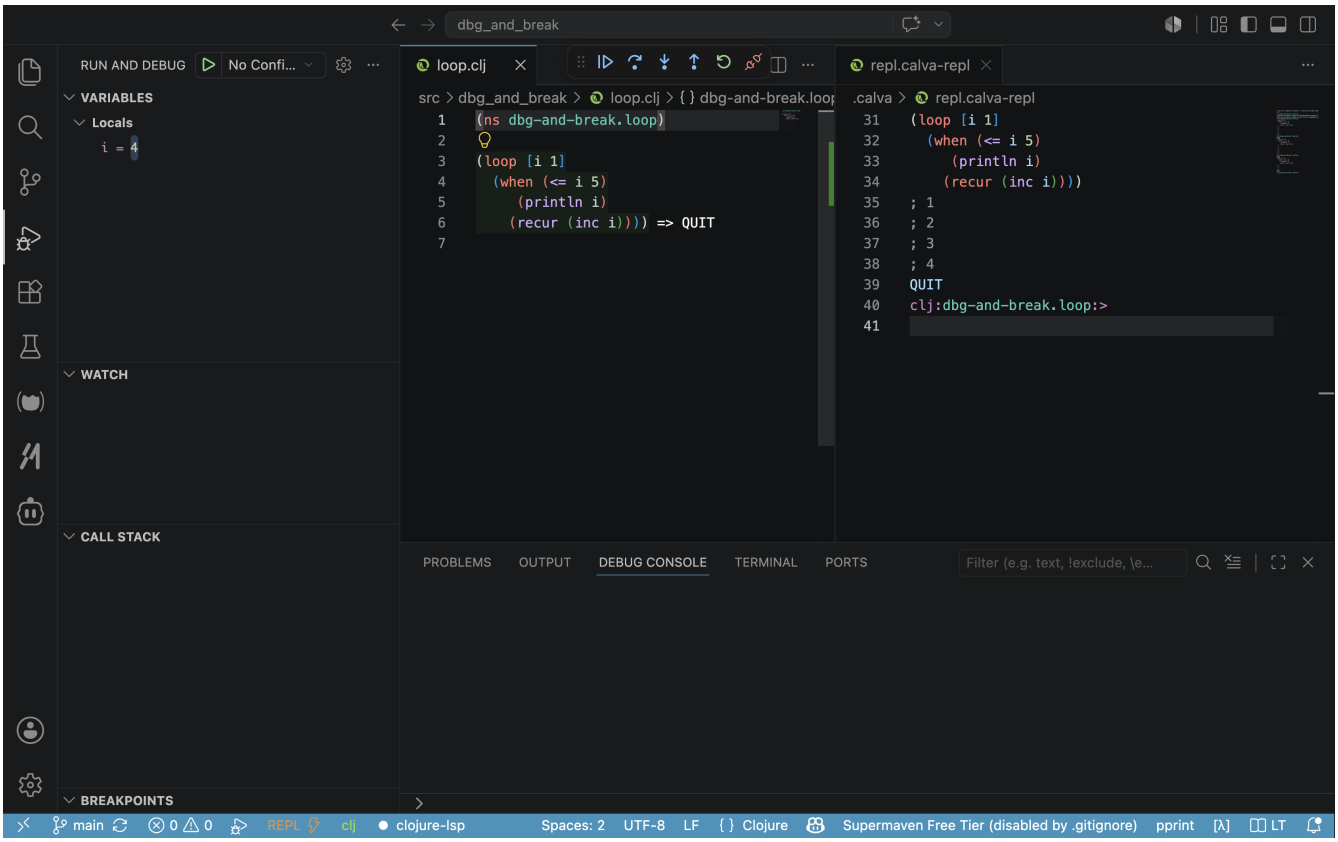
Press **Continue** one last time, and you will see that the `loop` form returns `nil`.



That is how you can debug your code using nREPL and Calva in a Leiningen project.

29.2. Quitting

To stop a debugging session, instrument the form again and press **Continue** until `i` reaches a value less than 6. Then, press the **Disconnect** button:



The program will quit. In this case, only values up to 4 were printed. The **Disconnect** button is very useful when you have finished debugging and want to stop the process.

29.3. Using explicit #dbg

Rather than using the VS Code menu to instrument a form, you can place `#dbg` directly in front of the form in your code:

src/dbg_and_break/explicit_debug.clj

```
(ns dbg-and-break.explicit-debug)

#dbg
(loop [i 1]
  (when (<= i 5)
     (println i)
    (recur (inc i))))
```

The debugging experience is identical to the previous method. After adding `#dbg` in front of the form, place your cursor within the form and press `alt`+`enter` or `option`+`enter` to start the debugger.

29.4. #break

I initially tried using `#break` in the program below, but it did not work. After consulting an AI, I found the following example:

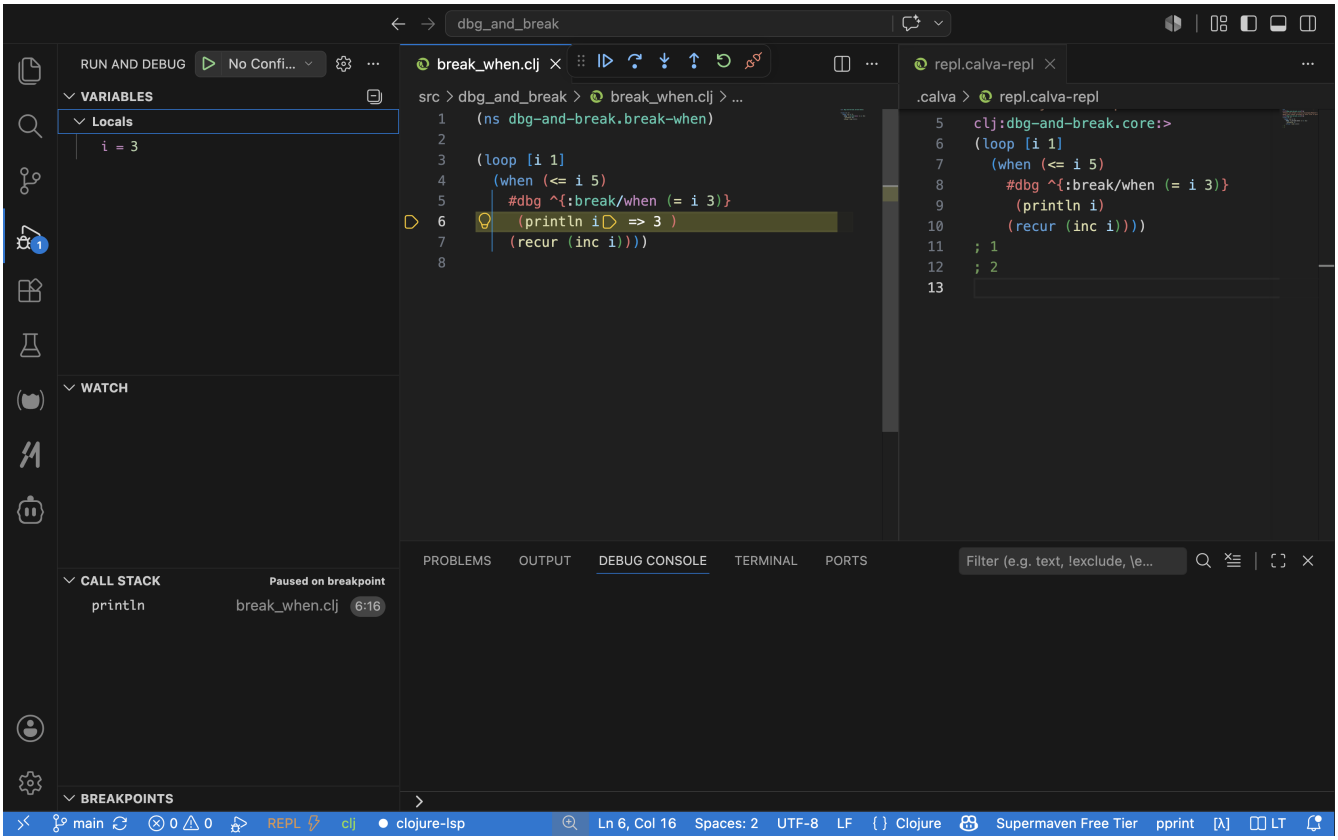
src/dbg_and_break/break_when.clj

```
(ns dbg-and-break.loop)

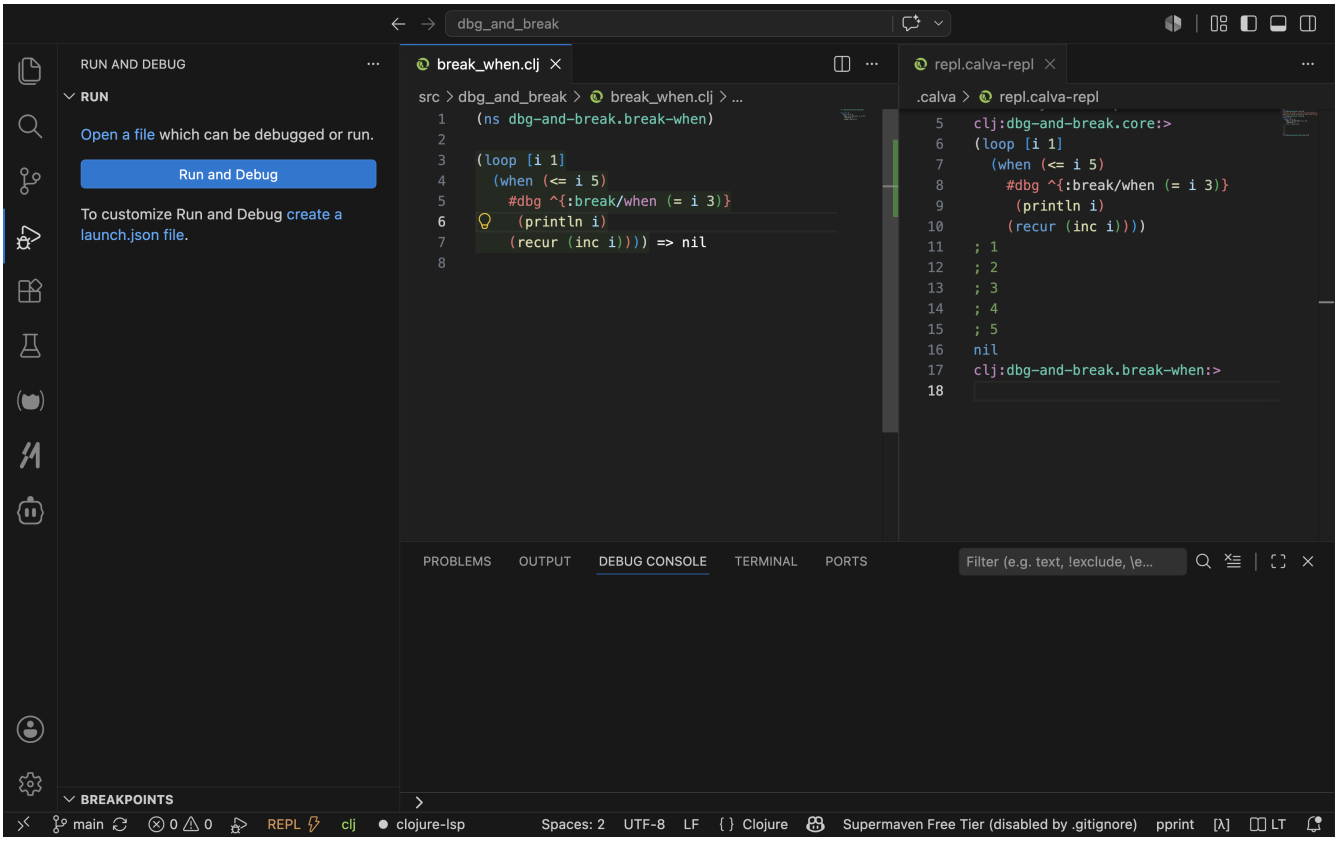
(loop [i 1]
  (when (<= i 5)
    #dbg ^{:break/when (= i 3)}
    (println i)
    (recur (inc i))))
```

In the line `#dbg ^{:break/when (= i 3)}`, the metadata `^{:break/when (= i 3)}` tells the debugger to break specifically when the value of `i` is `3`, at which point the `#dbg` instrumentation kicks in.

Jack in, place your cursor in the form, and press `alt`+`enter` or `option`+`enter`. You should see the following:



As shown in the image, 1 and 2 are printed, and the program stops when i is 3. Hit the **Continue** button, and it will run until i is 6, printing all values from 1 to 5.



When the program breaks and #dbg is active, you can inspect the value of i and perform various debugging tasks. While this is a simple example, these types of conditional breaks are extremely helpful in complex programs dealing with many values.

To further demonstrate the use of `break`, consider this program:

src/dbg_and_break/apply_discount.clj

```
(ns dbg-and-break.apply-discount)

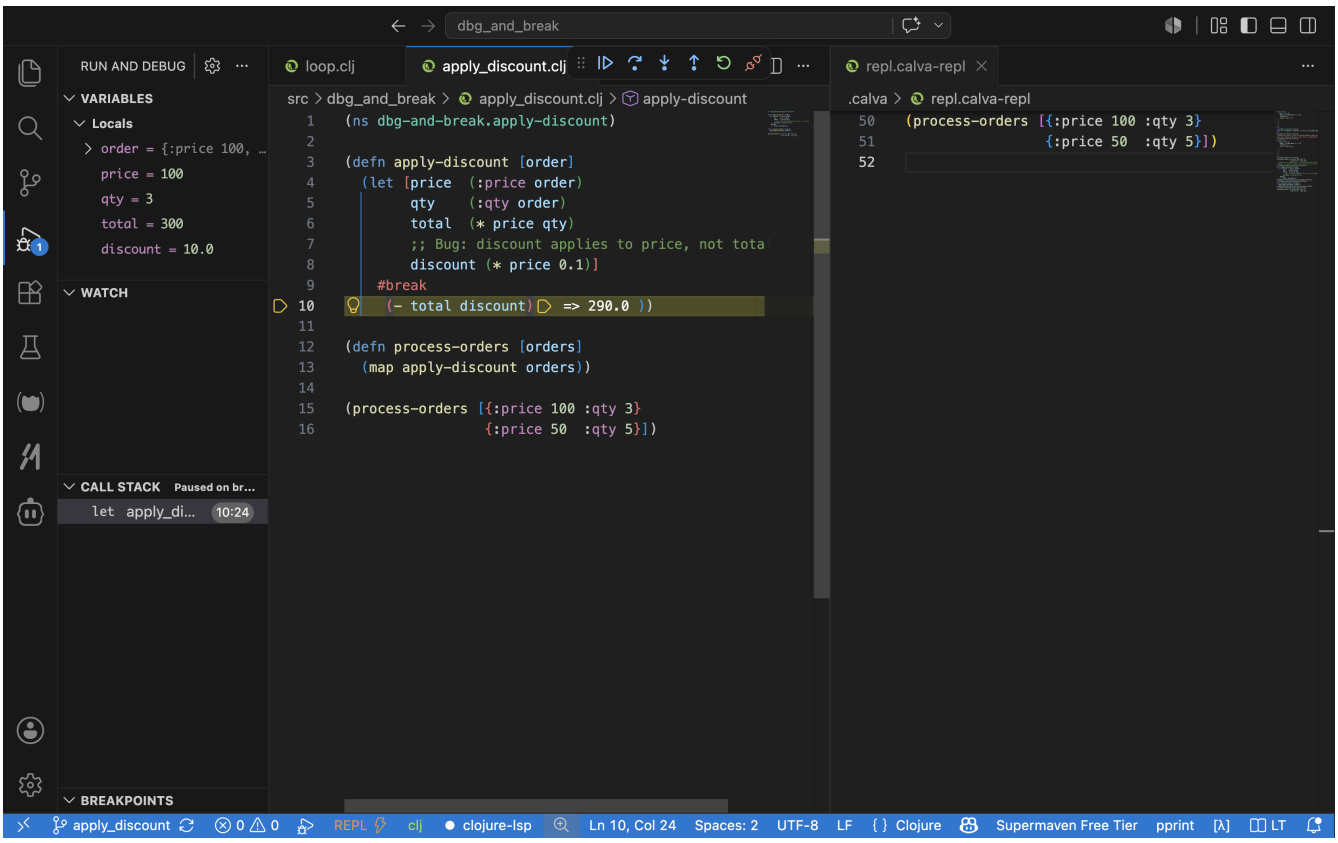
(defn apply-discount [order]
  (let [price  (:price order)
        qty    (:qty order)
        total  (* price qty)
        ;; Bug: discount applies to price, not total
        discount (* price 0.1)]
    #break
     (- total discount)))

(defn process-orders [orders]
  (map apply-discount orders))

(process-orders [{:price 100 :qty 3}
                 {:price 50  :qty 5}])
```

Jack in and load the `apply-discount` function into the REPL by placing the cursor in it and pressing `alt`+`enter` or `option`+`enter`. Do the same for `process-orders`.

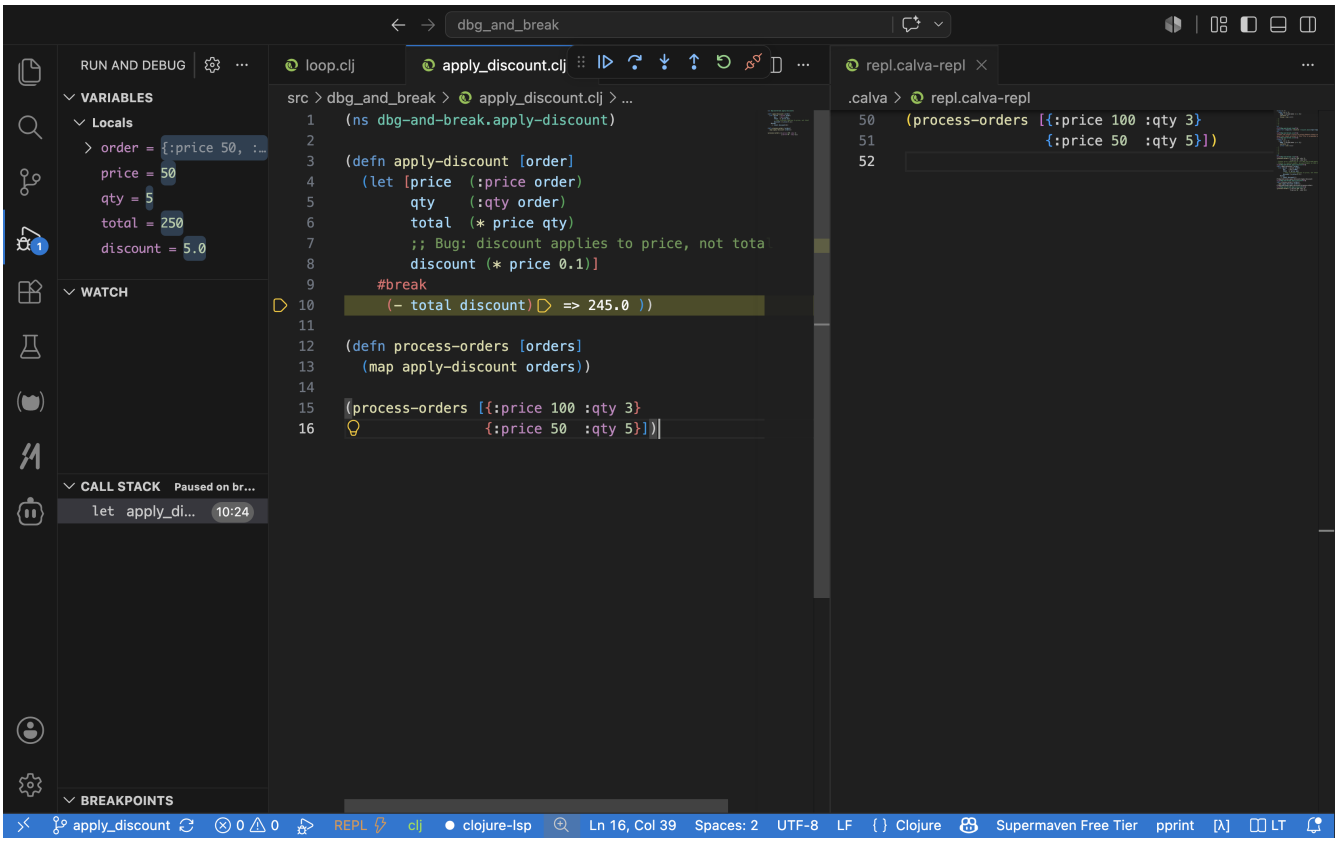
Now, place the cursor in the `(process-orders ⋯)` form and press `alt`+`enter` or `option`+`enter`. You will see the following:



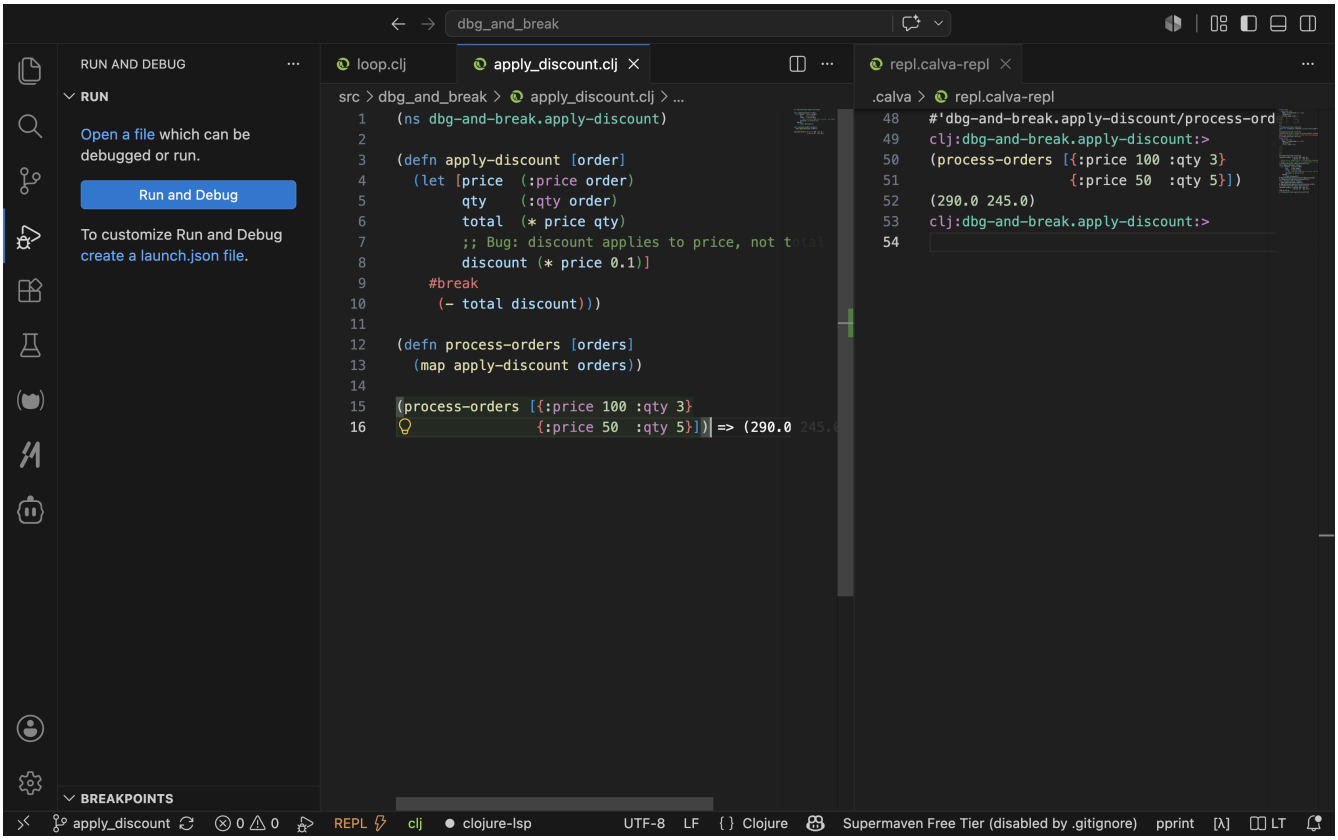
The debugger breaks at the `(- total discount)` line. You can see the values of `total`, `discount`, `price`,

and `qty` on the left, as well as the `order` map. Notice that the `(- total discount)` line is highlighted in red, showing it has returned `290`.

Hit the **Continue** button, and the program will stop again, and the value of `(- total discount)` will change from `290` to `245`.



Hit **Continue** again, and the program will complete execution:



The output of

```
(process-orders [{:price 100 :qty 3}
                 {:price 50  :qty 5}])
```

will be the list `(290.0 245.0)`. You can see it in the REPL output at the right of the image above.

Chapter 30. File Operations

In this section, let's see how to deal with files in Clojure. We will also look at some popular file formats and how to handle them.

30.1. Text

Text files contain nothing other than plain text, letters, and numbers. They are among the easiest to deal with. Open an empty Clojure file, let's call it `text_files.clj`, and execute the following:

```
(spit "hello.txt" "Hello World!")
```

A file called `hello.txt` is created with the content `Hello World!`.

The function `spit` takes two arguments: the first is the filename and the second is the content to be written to the file. Once you execute it, you have a file with content. It is as simple as that.

`spit` is used for writing to a file and `slurp` for reading from one. Let's now read the content of `hello.txt` and print it:

```
(println (slurp "hello.txt"))
```

Output

```
Hello World!
```

`(slurp "hello.txt")` reads the content of `hello.txt` and returns it as a string, `println` prints it out as shown above.

Now if you want to add an extra line to the file, we can use `:append true` as shown below:

```
(spit "hello.txt" "\nHello Mars!" :append true)

(println (slurp "hello.txt"))
```

Output

```
Hello World!
Hello Mars!
```

Rather than the entire file being erased, "\nHello Mars!" is appended to the end of the file `hello.txt`.

Now let's delete the file `hello.txt`:

```
(require '[clojure.java.io :as io])

(io/delete-file "hello.txt")
```

To delete a file, we require the `clojure.java.io` library using `(require '[clojure.java.io :as io])`, and then we call the `io/delete-file` function with the filename as an argument: `(io/delete-file "hello.txt")`.

The file `hello.txt` will be deleted.

The entire source code for this section is listed below, and you can get it from here https://gitlab.com/clojure-book/code/-/raw/master/text_files.clj

text_files.clj

```
;; text_files.clj

(spit "hello.txt" "Hello World!")

(println (slurp "hello.txt"))

;; appending content to files

(spit "hello.txt" "\nHello Mars!" :append true)

(println (slurp "hello.txt"))

;; deleting files

(require '[clojure.java.io :as io])

(io/delete-file "hello.txt")
```

30.2. edn

Find the source code here https://gitlab.com/clojure-book/code/-/raw/master/edn_file.clj

Watch video for this section here https://yu7.in/clj-edn

EDN, or Extensible Data Notation https://github.com/edn-format/edn, is the preferred way for Clojure to store and transfer data. Support for EDN is built into Clojure. To learn how to deal with EDN, let's create a simple EDN file as shown below:

spell_numbers.edn

```
{1 "One" 2 "Two" 3 "Three"}
```

Now let's create a Clojure file to read and write this EDN file, let's name it `edn_file.clj`. First, let's require the Clojure EDN library:

```
(require '[clojure.edn :as edn])
```

Output

```
nil
```

Now let's read the EDN file `spell_numbers.edn` and store it in a variable named `spell-numbers`:

```
(def spell-numbers
  (edn/read-string (slurp "spell_numbers.edn")))
```

Output

```
#'user/spell-numbers
```

Now let's print the `spell-numbers` variable:

```
(println spell-numbers)
```

Output

```
{1 One, 2 Two, 3 Three}
```

Now let's append a new value to the `spell-numbers` map; we will add the key `4` with the value `"Four"`:

```
(assoc spell-numbers 4 "Four"))
```

Convert it into a string:

```
(prn-str (assoc spell-numbers 4 "Four"))
```

and write it into the `spell_numbers.edn` file:

```
(spit "spell_numbers.edn" (prn-str (assoc spell-numbers 4 "Four")))
```

Now let's see the content of the `spell_numbers.edn` file:

```
{1 "One", 2 "Two", 3 "Three", 4 "Four"}
```

As you can see `4 "Four"` is added to the map.

Now let's read the `spell_numbers.edn` file and store it in a variable named `spell-numbers-appended`:

```
(def spell-numbers-appended
  (edn/read-string (slurp "spell_numbers.edn")))
```

Output

```
#'user/spell-numbers-appended
```

Now let's print the `spell-numbers-appended` variable:

```
(println spell-numbers-appended)
```

Output

```
{1 One, 2 Two, 3 Three, 4 Four}
```

Now let's overwrite the `spell_numbers.edn` file with the `spell-numbers` variable:

```
(spit "spell_numbers.edn" (prn-str spell-numbers))
```

Output

```
nil
```

Now we are back to the original `spell_numbers.edn` file as shown below:

```
{1 "One", 2 "Two", 3 "Three"}
```

You can get the full code of `edn_file.clj` at https://gitlab.com/clojure-book/code/-/raw/master/edn_file.clj

edn_file.clj

```
;; edn_file.clj

(require '[clojure.edn :as edn])
```

```
(def spell-numbers
  (edn/read-string (slurp "spell_numbers.edn")))

(println spell-numbers)

(spit "spell_numbers.edn" (prn-str (assoc spell-numbers 4 "Four")))

(def spell-numbers-appended
  (edn/read-string (slurp "spell_numbers.edn")))

(println spell-numbers-appended)

(spit "spell_numbers.edn" (prn-str spell-numbers))
```

30.3. CSV

Find the project source here https://gitlab.com/clojure-book/file-ops/-/tree/csv_ops

Watch the video for this section here https://yu7.in/clj-csv

CSV stands for Comma-Separated Values. It is a very common file format for storing tabular data. In Clojure, we use the `data.csv` library to read from and write to CSV files. You can find the library here: https://github.com/clojure/data.csv

Let's first create a Leiningen project named `file-ops`:

```
$ lein new app file-ops
```

In `project.clj`:

project.clj

```
(defproject file-ops "0.1.0-SNAPSHOT"
  :description "FIXME: write description"
  :url "http://example.com/FIXME"
  :license {:name "EPL-2.0 OR GPL-2.0-or-later WITH Classpath-exception-2.0"
            :url "https://www.eclipse.org/legal/epl-2.0/"}
  :dependencies [[org.clojure/clojure "1.11.1"]
                 [org.clojure/data.csv "1.1.0"]]
  :repl-options {:init-ns file-ops.core})
```

Add the line `[org.clojure/data.csv "1.1.0"]` to the `:dependencies` vector as shown above.

Now let's create a file called `in-file.csv` with the following content:

in-file.csv

```
name, profession
Karthikeyan, Clojure Programmer
Pari, Data Engineer
```

Now, let's create a file named `src/file_ops/csv_ops.clj` in the project and add this content:

```
(ns file-ops.csv-ops
  (:require [clojure.data.csv :as csv]
            [clojure.java.io :as io]))
```

`clojure.data.csv` is used for handling CSV content and is imported as `csv`. `clojure.java.io` is used for file I/O and is imported as `io`.

Now jack-in and add this function:

```
(defn csv-reader [filename]
  (with-open [reader (io/reader filename)]
    (doall
     (csv/read-csv reader))))
```

To understand how this works, let's break it down. First, we define a function named `csv-reader`:

```
(defn csv-reader [])
```

We make it accept an argument named `filename`:

```
(defn csv-reader [filename])
```

We open the file:

```
(defn csv-reader [filename]
  (with-open [reader (io/reader filename)]))
```

We read the file using `csv/read-csv`:

```
(defn csv-reader [filename]
  (with-open [reader (io/reader filename)]
     (csv/read-csv reader)))
```

Since `read-csv` is lazy, we wrap it with `doall` to ensure the file is read before the reader is closed by `with-open`:

```
(defn csv-reader [filename]
  (with-open [reader (io/reader filename)]
    (doall
     (csv/read-csv reader))))
```

Load it into the REPL by pressing Alt+Enter or Option+Enter. Now let's read our CSV:

```
(csv-reader "in-file.csv")
```

Output:

```
(["name" "profession"] ["Karthikeyan" "Clojure Programmer"] ["Pari" "Data Engineer"])
```

As you can see, instead of reading the CSV as a plain text file, we get a sequence of vectors, which is much easier to work with.

Similarly, we can write CSV files using the `csv/write-csv` function. Let's define a writer function below:

```
(defn csv-writer [filename data]
  (with-open [writer (io/writer filename)]
    (doall
     (csv/write-csv writer data))))
```

Now let's write a CSV:

```
(csv-writer "out-file.csv"
            [["name" "profession"]
             ["Karthikeyan" "Clojure Programmer"]
             ["Pari" "Data Engineer"]
             ["Bill Gates" "Shackles you up"]
             ["Richard M Stallman" "Unshackles you"]])
```

Examining `out-file.csv`, we have:

out-file.csv

```
name,profession
Karthikeyan,Clojure Programmer
Pari,Data Engineer
Bill Gates,Shackles you up
Richard M Stallman,Unshackles you
```

Clojure programmers are often more comfortable working with maps than sequences of vectors, so

let's write a function to convert CSV data into maps.

First, we define a function named `csv-data->maps`:

```
(defn csv-data->maps [])
```

This function should take `csv-data` as an argument:

```
(defn csv-data->maps [csv-data])
```

The first row of the CSV is the header:

```
(defn csv-data->maps [csv-data]
  (first csv-data))
```

Let's convert the first row to keywords:

```
(defn csv-data->maps [csv-data]
  (->> (first csv-data) ;; First row is the header
       (map keyword) ;; Remove this line if you prefer string keys
  ))
```

Now we repeat the header for each data row:

```
(defn csv-data->maps [csv-data]
  (->> (first csv-data) ;; First row is the header
       (map keyword) ;; Remove this line if you prefer string keys
       repeat))
```

Now let's get the rest of the data using `(rest csv-data)`:

```
(defn csv-data->maps [csv-data]
  (->> (first csv-data) ;; First row is the header
       (map keyword) ;; Remove this line if you prefer string keys
       repeat)
  (rest csv-data))
```

Now let's zipmap the header with the rest of the data:

```
(defn csv-data->maps [csv-data]
  (map zipmap
       (->> (first csv-data) ;; First row is the header
            (map keyword) ;; Remove this line if you prefer string keys
```

```
            repeat)
       (rest csv-data)))
```

And we are done. Now let's test it:

```
(csv-data->maps (csv-reader "in-file.csv"))
```

Output:

```
({:name "Karthikeyan", :profession "Clojure Programmer"} {:name "Pari", :profession
"Data Engineer"})
```

Now we have a nice sequence of maps, which is a format Clojure programmers are familiar with.

The full code for this section is available here: https://gitlab.com/clojure-book/file-ops/-/raw/csv_ops/src/file_ops/csv_ops.clj

src/file_ops/csv_ops.clj

```
;; csv_ops.clj
;; https://github.com/clojure/data.csv

(ns file-ops.csv-ops
  (:require [clojure.data.csv :as csv]
            [clojure.java.io :as io]))

(defn csv-reader [filename]
  (with-open [reader (io/reader filename)]
    (doall
     (csv/read-csv reader))))

(csv-reader "in-file.csv")

(defn csv-writer [filename data]
  (with-open [writer (io/writer filename)]
    (doall
     (csv/write-csv writer data))))

(csv-writer "out-file.csv"
            [["name" "profession"]
             ["Karthikeyan" "Clojure Programmer"]
             ["Pari" "Data Engineer"]
             ["Bill Gates" "Shackles you up"]
             ["Richard M Stallman" "Unshackles you"]])

(defn csv-data->maps [csv-data]
  (map zipmap
       (->> (first csv-data) ;; First row is the header
```

```
            (map keyword) ;; Remove this line if you prefer string keys
            repeat)
       (rest csv-data)))

(csv-data->maps (csv-reader "in-file.csv"))
```

30.4. JSON

Find the project source here https://gitlab.com/clojure-book/file-ops/-/tree/json_ops/

Watch video for this section here https://yu7.in/clj-json

JSON stands for JavaScript Object Notation. It is a lightweight data-interchange format and a subset of JavaScript. As a text format, JSON is completely language-independent and is widely used to transfer data between a server and a web page. In this section, we will see how to use JSON in Clojure.

Let's create a file called `numbers.json` with the content as shown below:

numbers.json

```
{
    "one": 1,
    "two": 2,
    "three": 3
}
```

Add `[org.clojure/data.json "2.5.1"]` to `project.clj` as shown below. This line will pull the library needed to use JSON in our project.

project.clj

```
(defproject file-ops "0.1.0-SNAPSHOT"
  :description "FIXME: write description"
  :url "http://example.com/FIXME"
  :license {:name "EPL-2.0 OR GPL-2.0-or-later WITH Classpath-exception-2.0"
            :url "https://www.eclipse.org/legal/epl-2.0/"}
  :dependencies [[org.clojure/clojure "1.11.1"]
                 [org.clojure/data.csv "1.1.0"]
                 [org.clojure/data.json "2.5.1"]]
  :repl-options {:init-ns file-ops.core})
```

Restart the REPL o that the new dependency is loaded.

Create a file called `src/file_ops/json_ops.clj` and require the JSON library as shown below:

```
(ns file-ops.json-ops
```

```
  (:require [clojure.data.json :as json]))
```

Let's read the content of the `numbers.json` file as shown below:

```
(def numbers
  (json/read-str (slurp "numbers.json")))

numbers
```

Output

```
{"one" 1, "two" 2, "three" 3}
```

As you can see, `(slurp "numbers.json")` reads the content of `numbers.json`, which is then passed to `json/read-str` to convert it into a map. We store this result in a variable named `numbers` using `(def numbers (json/read-str (slurp "numbers.json")))`.

Now, let's add a new key-value pair to the `numbers` map:

```
(def more-numbers (assoc numbers "four" 4))

more-numbers
```

Output

```
{"one" 1, "two" 2, "three" 3, "four" 4}
```

We have added the pair `"four" 4` to the map and stored the result in a variable named `more-numbers`.

Now, let's write the `more-numbers` map to a file called `more-numbers.json`:

```
(spit "more-numbers.json" (json/write-str more-numbers))
```

When we open the `more-numbers.json` file, we can see the content as shown below:

more-numbers.json

```
{"one":1,"two":2,"three":3,"four":4}
```

The entire source code for this section is listed below, and you can get it from here https://gitlab.com/clojure-book/file-ops/-/raw/json_ops/src/file_ops/json_ops.clj

src/file_ops/json_ops.clj

```
;; json_ops.clj
;; https://github.com/clojure/data.json

(ns file-ops.json-ops
  (:require [clojure.data.json :as json]))

(def numbers
  (json/read-str (slurp "numbers.json")))

numbers

(def more-numbers (assoc numbers "four" 4))

more-numbers

(spit "more-numbers.json" (json/write-str more-numbers))
```

30.5. YAML

Find the project source here https://gitlab.com/clojure-book/file-ops/-/tree/yaml_ops

Watch the video here https://yu7.in/clj-yaml

YAML is a lighter form of JSON and is often used for configuration files. In this section, we will see how to use YAML in Clojure. First, let's add the `clj-yaml` library to our project, as shown in the line `[clj-commons/clj-yaml "1.0.29"]`.

project.clj

```
(defproject file-ops "0.1.0-SNAPSHOT"
  :description "FIXME: write description"
  :url "http://example.com/FIXME"
  :license {:name "EPL-2.0 OR GPL-2.0-or-later WITH Classpath-exception-2.0"
            :url "https://www.eclipse.org/legal/epl-2.0/"}
  :dependencies [[org.clojure/clojure "1.11.1"]
                 [org.clojure/data.csv "1.1.0"]
                 [org.clojure/data.json "2.5.1"]
                 [clj-commons/clj-yaml "1.0.29"]]
  :repl-options {:init-ns file-ops.core})
```

This will pull the necessary library for using YAML in our project.

Now, let's create a file called `yaml_ops.clj` with the content shown below:

```
(ns file-ops.yaml-ops
```

```
  (:require [clj-yaml.core :as yaml]))
```

The line `(:require [clj-yaml.core :as yaml])` requires the YAML library, which can then be referenced using the name `yaml`.

Rather than reading YAML content from a file, let's use it as a variable. We'll create a variable called `some-yaml` with the following content:

```
(def some-yaml "
todo:
  issues:
    - name: Fix all the things
      responsible:
        name: Rita
")
```

Now, let's convert the content of `some-yaml` to a map using `(yaml/parse-string some-yaml)`:

```
(def some-data (yaml/parse-string some-yaml))

some-data
```

Output

```
{:todo {:issues [{:name "Fix all the things", :responsible {:name "Rita"}}]}}
```

As you can see above, all the keys are keywords. If you prefer string keys, pass `:keywords false` as shown below:

```
(yaml/parse-string some-yaml :keywords false)
```

Output

```
{"todo" {"issues" ({"name" "Fix all the things", "responsible" {"name" "Rita"}})}}
```

This will get the keys as strings, as shown above.

Now, let's print the data in YAML format using `(println (yaml/generate-string some-data))`:

```
(println (yaml/generate-string some-data :dumper-options {:indent 2
                                                          :flow-style :block}))
```

Output

```
todo:
  issues:
  - name: Fix all the things
    responsible:
      name: Rita
```

Note that we have set the indentation to 2 and the flow-style to block, so that the output is neat and human-readable. Without these options, the output would look like this:

```
(println (yaml/generate-string some-data))
```

Output

```
todo:
  issues:
  - name: Fix all the things
    responsible: {name: Rita}
```

The entire YAML operation sequence is listed below. You can find the file here: https://gitlab.com/clojure-book/file-ops/-/raw/yaml_ops/src/file_ops/yaml_ops.clj

src/file_ops/yaml_ops.clj

```
;; yaml_ops.clj
;; https://github.com/clj-commons/clj-yaml/blob/master/doc/01-user-guide.adoc

(ns file-ops.yaml-ops
  (:require [clj-yaml.core :as yaml]))

(def some-yaml "
todo:
  issues:
    - name: Fix all the things
      responsible:
        name: Rita
")

(def some-data (yaml/parse-string some-yaml))

some-data

(yaml/parse-string some-yaml :keywords false)

(println (yaml/generate-string some-data :dumper-options {:indent 2
                                                          :flow-style :block}))
```

```
(println (yaml/generate-string some-data))
```

Chapter 31. Java Files in Clojure Project

Find the video for this section here: https://yu7.in/java-files-in-clojure-project

Find the source for this section here: https://yu7.in/W9qT0X

Clojure runs on top of Java, so it's easy to use Java programs in Clojure. To see how to do this, let's create a Leiningen project named `my-mixed-project`.

```
$ lein new app my-mixed-project
```

Now, move into the project directory:

```
$ cd my-mixed-project
```

Ensure that the structure of `my-mixed-project` is as shown below. We will now look at the contents of `project.clj`, `core.clj`, and `MyJavaClass.java`.

```
my-mixed-project/
├── project.clj
├── src/
│   ├── clojure/
│   │   └── my_mixed_project/core.clj
│   └── java/
│       └── my_mixed_project/MyJavaClass.java
```

First, let's examine `MyJavaClass.java`.

src/java/my_mixed_project/MyJavaClass.java

```
package my_mixed_project;

public class MyJavaClass {
    public static String greet(String name) {
        return "Hello from Java, " + name + "!";
    }
}
```

If you aren't familiar with Java, don't worry—you can skip this section and everything will still work. For those who know Java, this file defines a package named `my_mixed_project`, a class named `MyJavaClass`, and a static method named `greet` that takes a `String` parameter named `name`.

Now, look at the `project.clj` file below. Note the line `:java-source-paths ["src/java"]`; this tells Leiningen that our Java source files are located in the `src/java` folder.

project.clj

```
(defproject my-mixed-project "0.1.0-SNAPSHOT"
  :description "A Leiningen project with both Clojure and Java"
  :dependencies [[org.clojure/clojure "1.11.1"]]
  :source-paths ["src/clojure"]
  :java-source-paths ["src/java"]
  :main my-mixed-project.core)
```

Similarly, the line `:source-paths ["src/clojure"]` tells Leiningen that our Clojure source files are located in the `src/clojure` folder.

Now, in the `src/clojure/my_mixed_project` folder, create a file named `core.clj` and add the following code.

src/clojure/my_mixed_project/core.clj

```
(ns my-mixed-project.core
  (:import [my_mixed_project MyJavaClass]))

(defn -main [& args]
  (println (MyJavaClass/greet "Clojure Developer")))
```

Let's break down the code in `core.clj` step-by-step. First, we define the namespace:

src/clojure/my_mixed_project/core.clj

```
(ns my-mixed-project.core)
```

Next, we specify that we want to import from the `my_mixed_project` Java package:

src/clojure/my_mixed_project/core.clj

```
(ns my-mixed-project.core
  (:import [my_mixed_project]))
```

Then, we import the specific `MyJavaClass`:

src/clojure/my_mixed_project/core.clj

```
(ns my-mixed-project.core
  (:import [my_mixed_project MyJavaClass]))
```

Now, let's define the main function:

src/clojure/my_mixed_project/core.clj

```
(ns my-mixed-project.core
  (:import [my_mixed_project MyJavaClass]))
```

```
(defn -main [& args])
```

Inside the main function, we call the `MyJavaClass/greet` method:

src/clojure/my_mixed_project/core.clj

```
(ns my-mixed-project.core
  (:import [my_mixed_project MyJavaClass]))

(defn -main [& args]
  (MyJavaClass/greet))
```

Now, we pass the argument `"Clojure Developer"` to it:

src/clojure/my_mixed_project/core.clj

```
(ns my-mixed-project.core
  (:import [my_mixed_project MyJavaClass]))

(defn -main [& args]
  (MyJavaClass/greet "Clojure Developer"))
```

Finally, we wrap the call in a `println` function to print the output:

src/clojure/my_mixed_project/core.clj

```
(ns my-mixed-project.core
  (:import [my_mixed_project MyJavaClass]))

(defn -main [& args]
  (println (MyJavaClass/greet "Clojure Developer")))
```

Now, let's run the project:

```
$ lein run
Hello from Java, Clojure Developer!
```

The output `Hello from Java, Clojure Developer!` is printed to the console.

We have successfully written a Java file and integrated it into a Clojure project.

Chapter 32. JAR files in Clojure project

Find video for this section here https://yu7.in/jar-files-in-clojure-project

In this section, we will see how to include JAR files in Clojure projects.

32.1. Creating a JAR file

Find source code for this section here https://gitlab.com/clojure-book/create_jar_file

If you would like to know how to create your own JAR files, read this section; otherwise, skip to the next. Let's create a directory called `create_jar`.

```
$ mkdir create_jar
```

Move into the directory:

```
$ cd create_jar
```

Create a folder named `myjar` and a file named `HelloPrinter.java` in it. The folder structure should be as shown below:

```
.
└── myjar
    └── HelloPrinter.java
```

Now add the following code to `HelloPrinter.java`:

```
// HelloPrinter.java

package myjar;

public class HelloPrinter {
    public static void printHello() {
        System.out.println("Hello, World from the jar!");
    }
}
```

In the code above, we use a package called `myjar`, which matches the name of the folder where `HelloPrinter.java` is located. Next, we have the class `HelloPrinter`. This class has a method called `printHello` which prints the message "Hello, World from the jar!".

Let's compile this file using `javac`:

```
$ javac -d java-classes myjar/HelloPrinter.java
```

Once compiled, you will see that the folder `java-classes/myjar/` has been created, with a class file named `HelloPrinter.class` in it. This `.class` file contains the Java bytecode.

```
.
├── java-classes
│   └── myjar
│       └── HelloPrinter.class
└── myjar
    └── HelloPrinter.java
```

Now we need to convert this into a JAR file. To do that, use the following command:

```
$ jar cf hello-printer.jar -C java-classes .
```

The resulting file structure will look like this:

```
.
├── hello-printer.jar
├── java-classes
│   └── myjar
│       └── HelloPrinter.class
└── myjar
    └── HelloPrinter.java
```

Notice that the `hello-printer.jar` file has been created; this is the file we will use.

32.2. Using the JAR file

Find source code for this section here https://gitlab.com/clojure-book/hello_jar_clj

To use the JAR file, let's create a Leiningen project:

```
$ lein new hello-jar-clj
```

The project structure should look like this:

```
hello-jar-clj/
├── CHANGELOG.md
├── doc
│   └── intro.md
├── lib
```

```
│   └── hello-printer.jar
├── LICENSE
├── project.clj
├── README.md
├── resources
├── src
│   └── hello_jar_clj
│       └── core.clj
├── target
└── test
    └── hello_jar_clj
        └── core_test.clj
```

Now, copy the JAR file you created into the `lib` folder. Then, notice the `:classpath` value in `project.clj`:

project.clj

```
(defproject hello-jar-clj "0.1.0-SNAPSHOT"
  :description "Demo using Java jar in Clojure"
  :dependencies [[org.clojure/clojure "1.11.1"]]
  :classpath ["lib/hello-printer.jar"]
  :main hello-jar-clj.core)
```

We specify the exact location of the JAR file. Now, add the following code to `src/hello_jar_clj/core.clj`:

src/hello_jar_clj/core.clj

```
(ns hello-jar-clj.core
  (:import [myjar HelloPrinter]))

(defn -main [& args]
  (HelloPrinter/printHello))
```

Let's explain the code. First, we define the namespace `hello-jar-clj.core`.

src/hello_jar_clj/core.clj

```
(ns hello-jar-clj.core)
```

Next, we import the `HelloPrinter` class from the `myjar` package.

src/hello_jar_clj/core.clj

```
(ns hello-jar-clj.core
  (:import [myjar HelloPrinter]))
```

Then, we define the main function:

src/hello_jar_clj/core.clj

```
(ns hello-jar-clj.core
  (:import [myjar HelloPrinter]))

(defn -main [& args])
```

Inside the main function, we call the `HelloPrinter/printHello` method.

src/hello_jar_clj/core.clj

```
(ns hello-jar-clj.core
  (:import [myjar HelloPrinter]))

(defn -main [& args]
  (HelloPrinter/printHello))
```

Now, let's run the project:

```
$ lein run
```

And we get the output:

```
Hello, World from the jar!
```

Chapter 33. Creating Your Own Libraries

Watch video for this section here: https://youtu.be/QWhpISM-d5Q

In this section, we are going to create a small Leiningen project, upload it to Clojars, pull that library into another project, and use it.

33.1. Creating a Clojure Project

Get the code for this section here: https://gitlab.com/clojure-book/printline

First, let's create a small project called printline:

```
$ lein new printline
```

Now, `cd` into the `printline` directory and change the file `src/printline/core.clj` to have this content:

```
(ns printline.core)

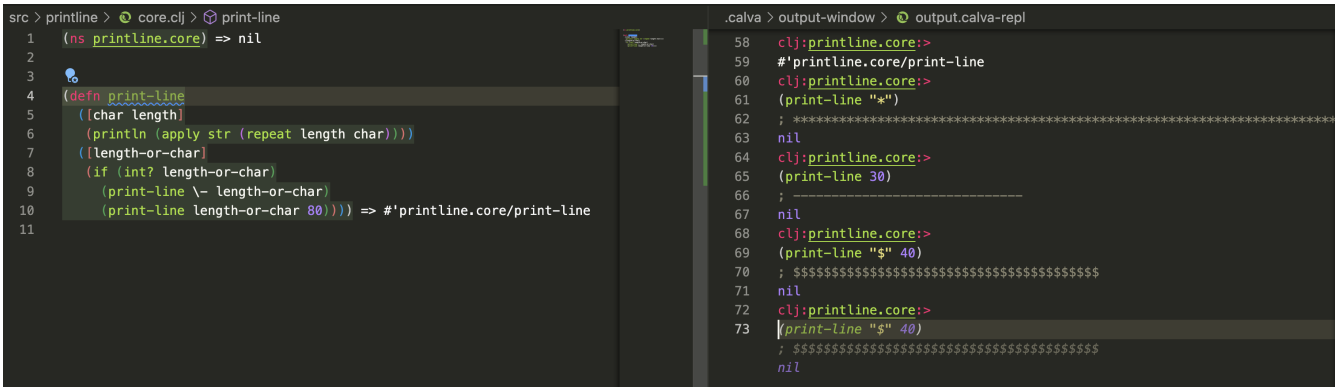
(defn print-line
  ([char length]
   (println (apply str (repeat length char))))
  ([length-or-char]
   (if (int? length-or-char)
     (print-line \- length-or-char)
     (print-line length-or-char 80))))
```

Jack into the project (see [1]), and in the REPL, let's try out the `print-line` function:

```
(print-line "*")
; ********************************************************************************
nil
```

```
(print-line "$" 20)
; $$$$$$$$$$$$$$$$$$$$
nil
```

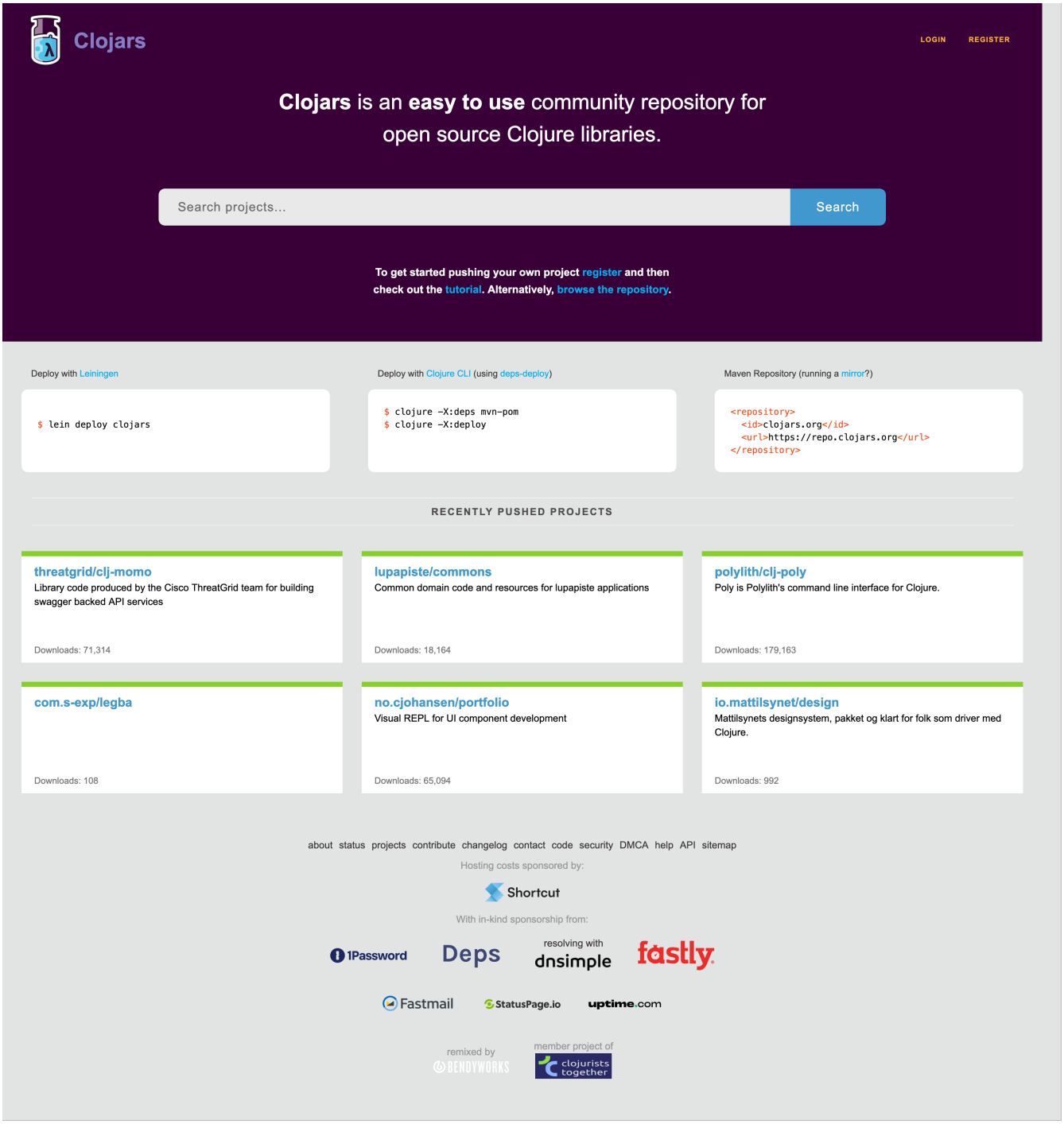
```
(print-line 30)
; ------------------------------
nil
```



It seems to work. Now, let's register ourselves on Clojars, a place where Clojure libraries can be hosted.

33.2. Clojars

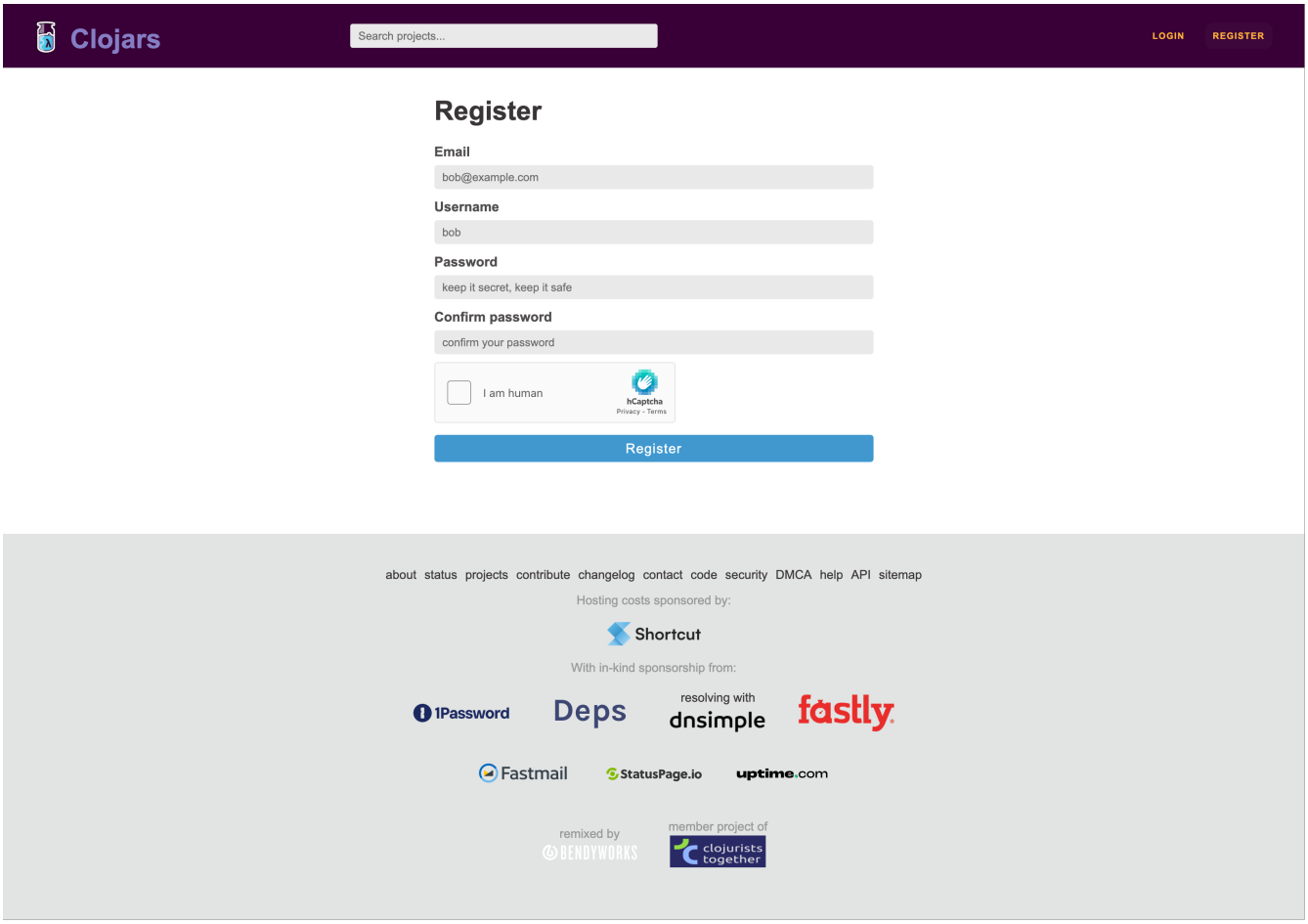
Visit https://clojars.org/. You should see a page like this:



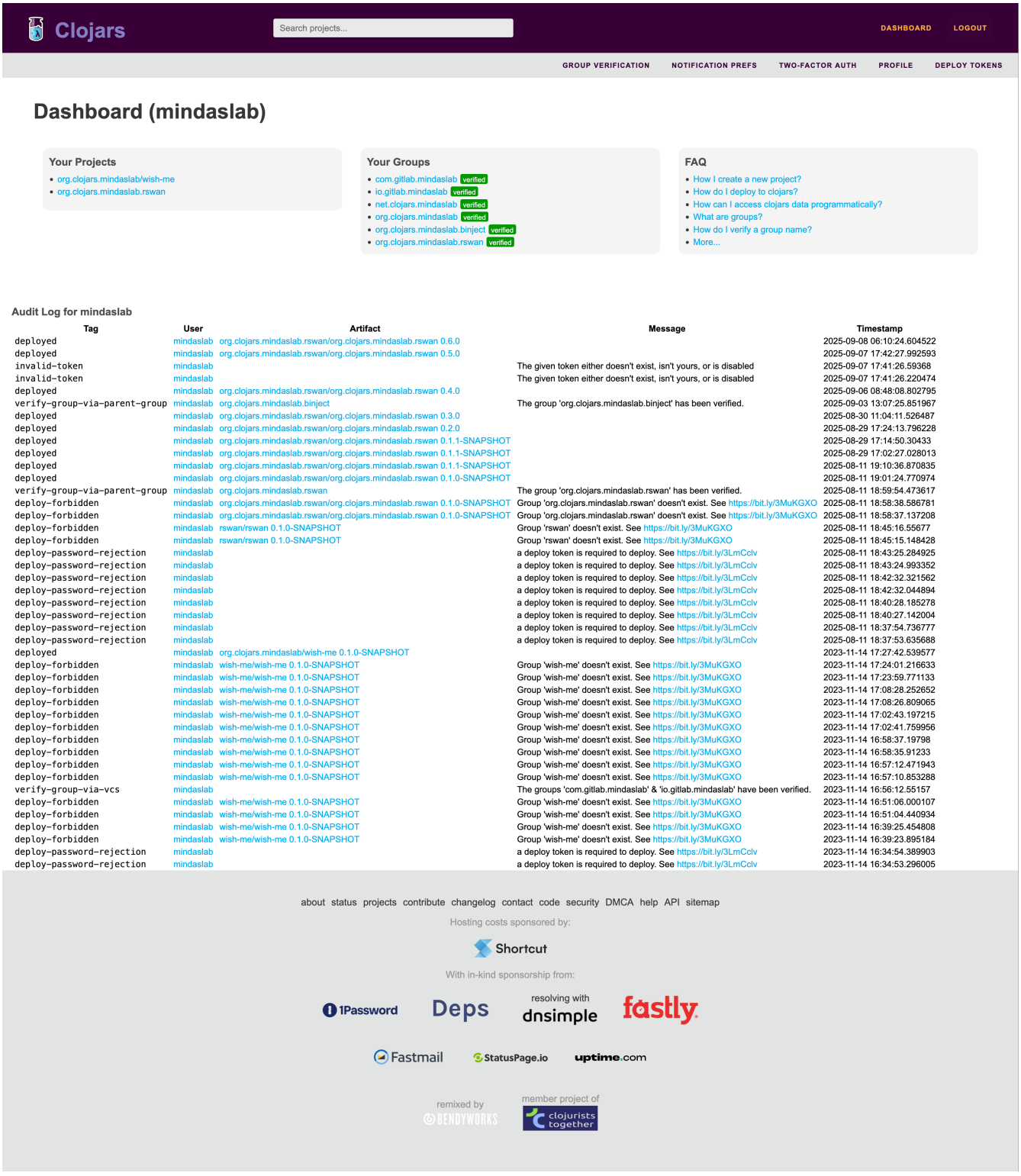
At the top right, you should see a link called Register; click it.

33.2.1. Registering

You will now see the Clojars registration page; fill in your details.



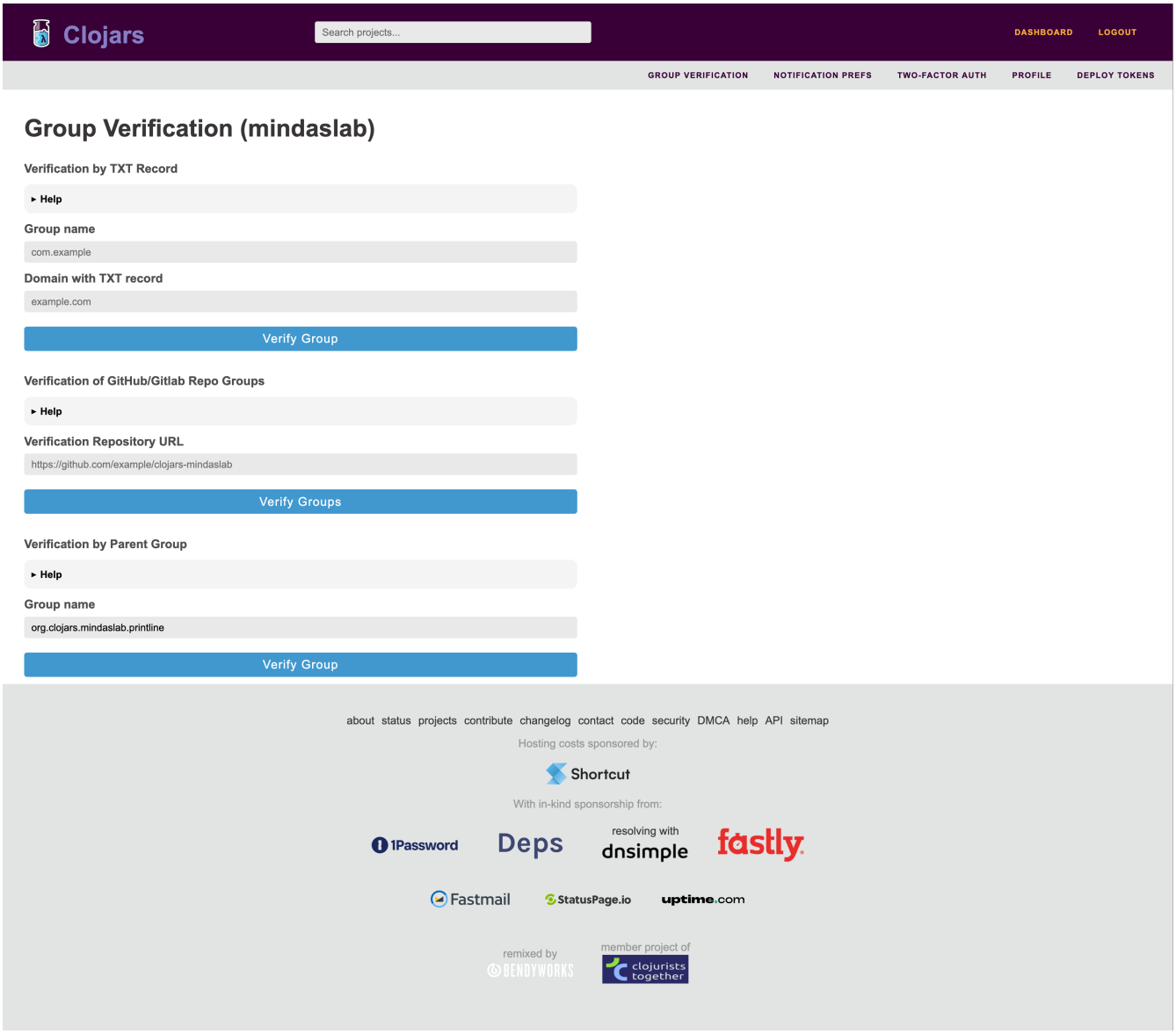
Since I have already registered and logged in, the image below shows what my dashboard looks like.


Clojars
Search projects...
DASHBOARD
LOGOUT
GROUP VERIFICATION
NOTIFICATION PREFS
TWO-FACTOR AUTH
PROFILE
DEPLOY TOKENS
Dashboard (mindaslab)
Your Projects
org.clojars.mindaslab/wish-me
org.clojars.mindaslab.rswan
Your Groups
com.gitlab.mindaslab verified
io.gitlab.mindaslab verified
net.clojars.mindaslab verified
org.clojars.mindaslab verified
org.clojars.mindaslab.binject verified
org.clojars.mindaslab.rswan verified
FAQ
How I create a new project?
How do I deploy to clojars?
How can I access clojars data programmatically?
What are groups?
How do I verify a group name?
More...
Audit Log for mindaslab
Tag User Artifact Message Timestamp
deployed mindaslab org.clojars.mindaslab.rswan/org.clojars.mindaslab.rswan 0.6.0 2025-09-08 06:10:24.604522
deployed mindaslab org.clojars.mindaslab.rswan/org.clojars.mindaslab.rswan 0.5.0 2025-09-07 17:42:27.992593
invalid-token mindaslab The given token either doesn't exist, isn't yours, or is disabled 2025-09-07 17:41:26.59368
invalid-token mindaslab The given token either doesn't exist, isn't yours, or is disabled 2025-09-07 17:41:26.220474
deployed mindaslab org.clojars.mindaslab.rswan/org.clojars.mindaslab.rswan 0.4.0 2025-09-06 08:48:08.802795
verify-group-via-parent-group mindaslab org.clojars.mindaslab.binject The group 'org.clojars.mindaslab.binject' has been verified. 2025-09-03 13:07:25.851967
deployed mindaslab org.clojars.mindaslab.rswan/org.clojars.mindaslab.rswan 0.3.0 2025-08-30 11:04:11.526487
deployed mindaslab org.clojars.mindaslab.rswan/org.clojars.mindaslab.rswan 0.2.0 2025-08-29 17:24:13.796228
deployed mindaslab org.clojars.mindaslab.rswan/org.clojars.mindaslab.rswan 0.1.1-SNAPSHOT 2025-08-29 17:14:50.30433
deployed mindaslab org.clojars.mindaslab.rswan/org.clojars.mindaslab.rswan 0.1.1-SNAPSHOT 2025-08-29 17:02:27.028013
deployed mindaslab org.clojars.mindaslab.rswan/org.clojars.mindaslab.rswan 0.1.1-SNAPSHOT 2025-08-11 19:10:36.870835
deployed mindaslab org.clojars.mindaslab.rswan/org.clojars.mindaslab.rswan 0.1.0-SNAPSHOT 2025-08-11 19:01:24.770974
verify-group-via-parent-group mindaslab org.clojars.mindaslab.rswan The group 'org.clojars.mindaslab.rswan' has been verified. 2025-08-11 18:59:54.473617
deploy-forbidden mindaslab org.clojars.mindaslab.rswan/org.clojars.mindaslab.rswan 0.1.0-SNAPSHOT Group 'org.clojars.mindaslab.rswan' doesn't exist. See https://bit.ly/3MuKGXO 2025-08-11 18:58:38.586781
deploy-forbidden mindaslab org.clojars.mindaslab.rswan/org.clojars.mindaslab.rswan 0.1.0-SNAPSHOT Group 'org.clojars.mindaslab.rswan' doesn't exist. See https://bit.ly/3MuKGXO 2025-08-11 18:58:37.137208
deploy-forbidden mindaslab rswan/rswan 0.1.0-SNAPSHOT Group 'rswan' doesn't exist. See https://bit.ly/3MuKGXO 2025-08-11 18:45:16.55677
deploy-forbidden mindaslab rswan/rswan 0.1.0-SNAPSHOT Group 'rswan' doesn't exist. See https://bit.ly/3MuKGXO 2025-08-11 18:45:15.148428
deploy-password-rejection mindaslab a deploy token is required to deploy. See https://bit.ly/3LmCclv 2025-08-11 18:43:25.284925
deploy-password-rejection mindaslab a deploy token is required to deploy. See https://bit.ly/3LmCclv 2025-08-11 18:43:24.993352
deploy-password-rejection mindaslab a deploy token is required to deploy. See https://bit.ly/3LmCclv 2025-08-11 18:42:32.321562
deploy-password-rejection mindaslab a deploy token is required to deploy. See https://bit.ly/3LmCclv 2025-08-11 18:42:32.044894
deploy-password-rejection mindaslab a deploy token is required to deploy. See https://bit.ly/3LmCclv 2025-08-11 18:40:28.185278
deploy-password-rejection mindaslab a deploy token is required to deploy. See https://bit.ly/3LmCclv 2025-08-11 18:40:27.142004
deploy-password-rejection mindaslab a deploy token is required to deploy. See https://bit.ly/3LmCclv 2025-08-11 18:37:54.736777
deploy-password-rejection mindaslab a deploy token is required to deploy. See https://bit.ly/3LmCclv 2025-08-11 18:37:53.635688
deployed mindaslab org.clojars.mindaslab/wish-me 0.1.0-SNAPSHOT 2023-11-14 17:27:42.539577
deploy-forbidden mindaslab wish-me/wish-me 0.1.0-SNAPSHOT Group 'wish-me' doesn't exist. See https://bit.ly/3MuKGXO 2023-11-14 17:24:01.216633
deploy-forbidden mindaslab wish-me/wish-me 0.1.0-SNAPSHOT Group 'wish-me' doesn't exist. See https://bit.ly/3MuKGXO 2023-11-14 17:23:59.771133
deploy-forbidden mindaslab wish-me/wish-me 0.1.0-SNAPSHOT Group 'wish-me' doesn't exist. See https://bit.ly/3MuKGXO 2023-11-14 17:08:28.252652
deploy-forbidden mindaslab wish-me/wish-me 0.1.0-SNAPSHOT Group 'wish-me' doesn't exist. See https://bit.ly/3MuKGXO 2023-11-14 17:08:26.809065
deploy-forbidden mindaslab wish-me/wish-me 0.1.0-SNAPSHOT Group 'wish-me' doesn't exist. See https://bit.ly/3MuKGXO 2023-11-14 17:02:43.197215
deploy-forbidden mindaslab wish-me/wish-me 0.1.0-SNAPSHOT Group 'wish-me' doesn't exist. See https://bit.ly/3MuKGXO 2023-11-14 17:02:41.759956
deploy-forbidden mindaslab wish-me/wish-me 0.1.0-SNAPSHOT Group 'wish-me' doesn't exist. See https://bit.ly/3MuKGXO 2023-11-14 16:58:37.19798
deploy-forbidden mindaslab wish-me/wish-me 0.1.0-SNAPSHOT Group 'wish-me' doesn't exist. See https://bit.ly/3MuKGXO 2023-11-14 16:58:35.91233
deploy-forbidden mindaslab wish-me/wish-me 0.1.0-SNAPSHOT Group 'wish-me' doesn't exist. See https://bit.ly/3MuKGXO 2023-11-14 16:57:12.471943
deploy-forbidden mindaslab wish-me/wish-me 0.1.0-SNAPSHOT Group 'wish-me' doesn't exist. See https://bit.ly/3MuKGXO 2023-11-14 16:57:10.853288
verify-group-via-vcs mindaslab The groups 'com.gitlab.mindaslab' & 'io.gitlab.mindaslab' have been verified. 2023-11-14 16:56:12.55157
deploy-forbidden mindaslab wish-me/wish-me 0.1.0-SNAPSHOT Group 'wish-me' doesn't exist. See https://bit.ly/3MuKGXO 2023-11-14 16:51:06.000107
deploy-forbidden mindaslab wish-me/wish-me 0.1.0-SNAPSHOT Group 'wish-me' doesn't exist. See https://bit.ly/3MuKGXO 2023-11-14 16:51:04.440934
deploy-forbidden mindaslab wish-me/wish-me 0.1.0-SNAPSHOT Group 'wish-me' doesn't exist. See https://bit.ly/3MuKGXO 2023-11-14 16:39:25.454808
deploy-forbidden mindaslab wish-me/wish-me 0.1.0-SNAPSHOT Group 'wish-me' doesn't exist. See https://bit.ly/3MuKGXO 2023-11-14 16:39:23.895184
deploy-password-rejection mindaslab a deploy token is required to deploy. See https://bit.ly/3LmCclv 2023-11-14 16:34:54.389903
deploy-password-rejection mindaslab a deploy token is required to deploy. See https://bit.ly/3LmCclv 2023-11-14 16:34:53.296005
about status projects contribute changelog contact code security DMCA help API sitemap
Hosting costs sponsored by:
Shortcut
With in-kind sponsorship from:
1Password
Deps
resolving with
dnsimple
fastly
Fastmail
StatusPage.io
uptime.com
remixed by
BENDYWORKS
member project of
clojurists together

Once you reach your dashboard, look at the top in the grey navigation bar. You will see a menu called 'Group Verification'; click it.

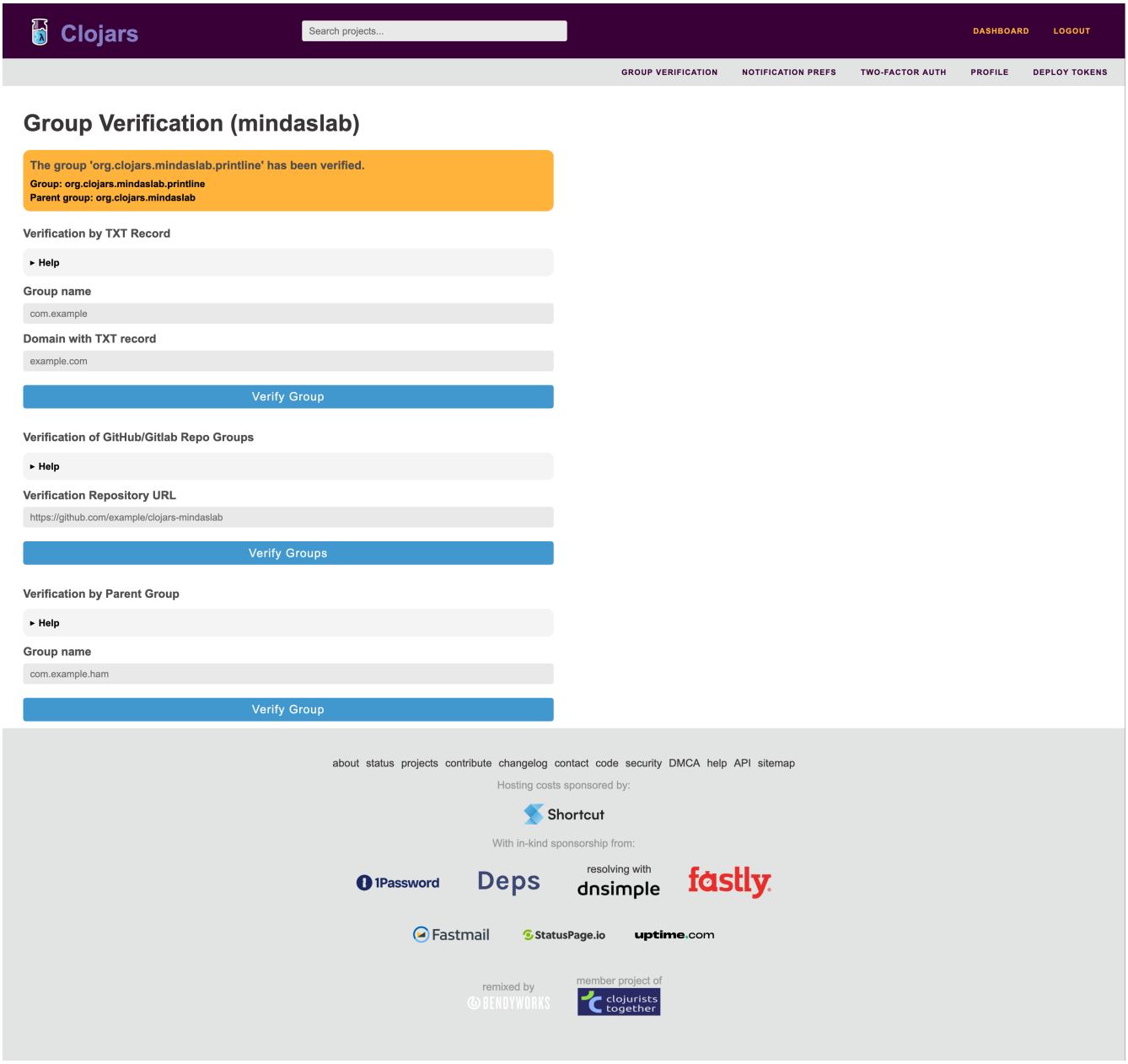
33.2.2. Creating a group

You will be taken to the Group Verification page. The easiest way to verify a group is to use Verification by Parent Group.



I have already been assigned a parent group named `org.clojars.mindaslab`, where `mindaslab` is my username. Now, in the Group name field, I need to create a subgroup called `printline`, so I fill it with `org.clojars.mindaslab.printline`. Then click the Verify Group button.

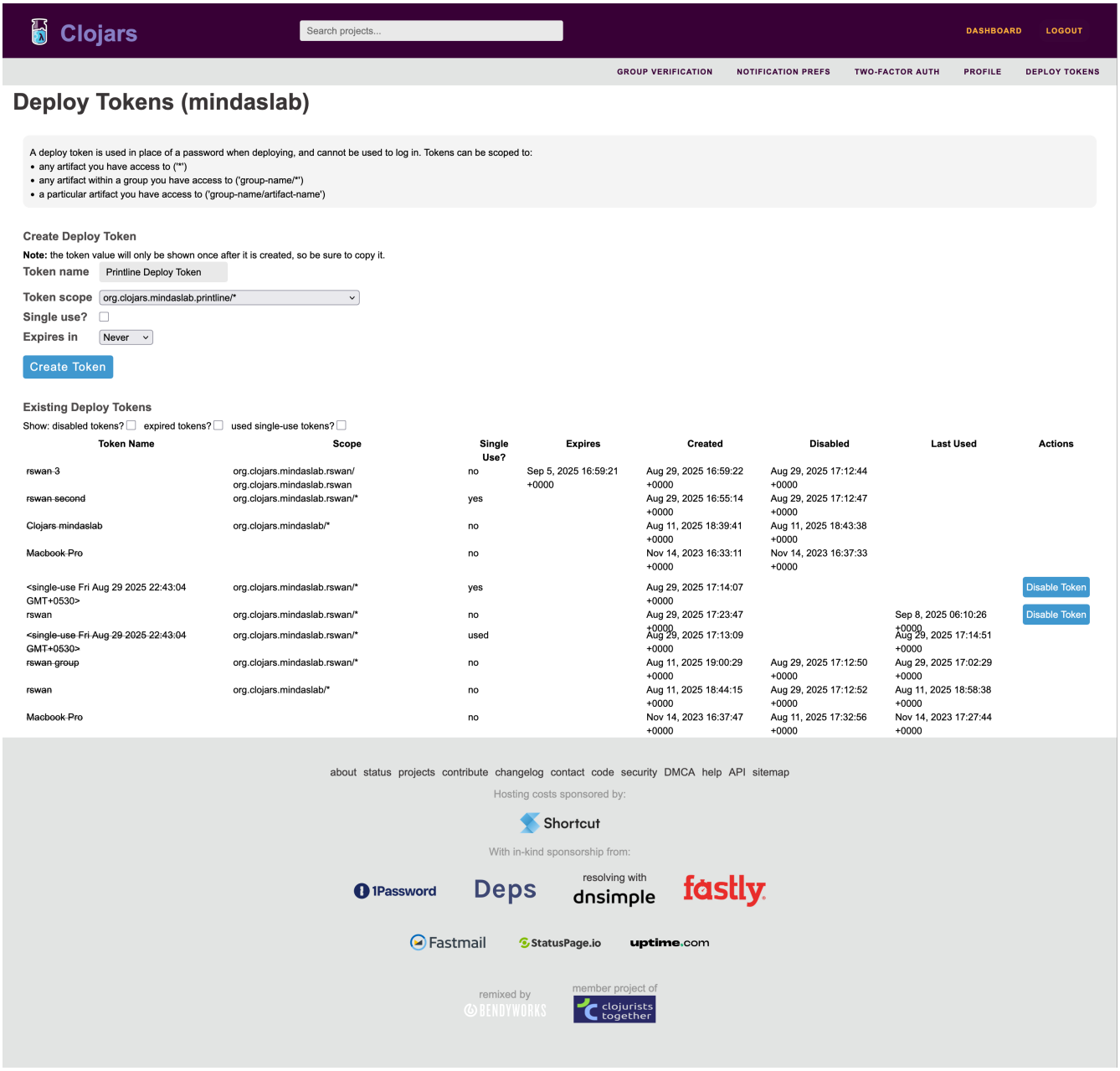
You will see a yellow notification stating that my group `org.clojars.mindaslab.printline` is verified, as shown below.



Now in the grey navbar at the top, you should see a menu called DEPLOY TOKENS. Click it.

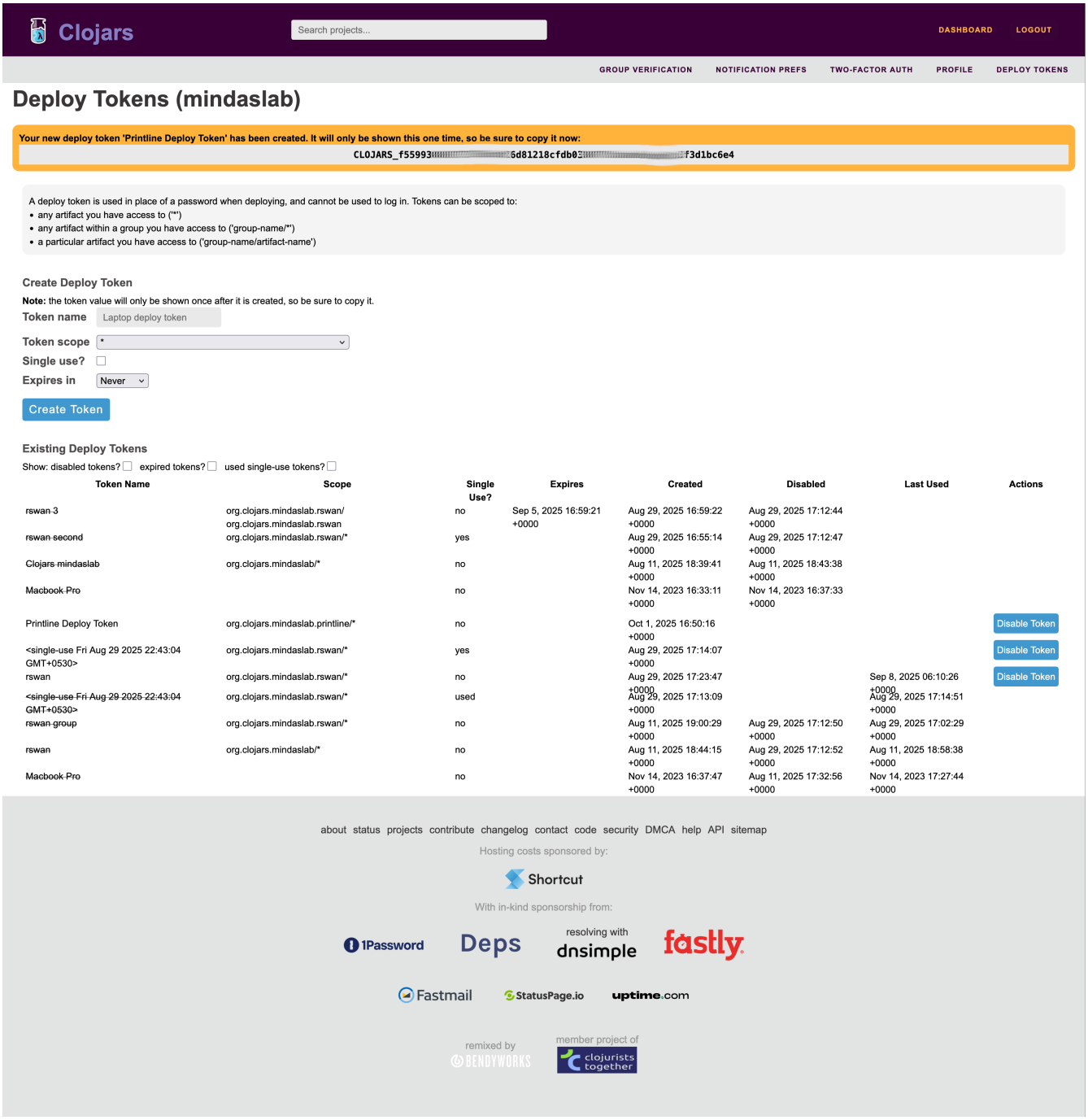
33.2.3. Getting a deployment token

In the Deploy Tokens section, as shown below:



Give the token a name that you can remember; I have used "Printline Deploy Token". For the scope, I have selected `org.clojars.mindaslab.printline`. I want this token to never expire, which I have specified in the "Expires in" field. Then click Create Token.

You will see a screen like this:


Clojars
Search projects...
DASHBOARD
LOGOUT
GROUP VERIFICATION
NOTIFICATION PREFS
TWO-FACTOR AUTH
PROFILE
DEPLOY TOKENS
Deploy Tokens (mindaslab)
Your new deploy token 'Printline Deploy Token' has been created. It will only be shown this one time, so be sure to copy it now:
CLOJARS_f55993[redacted]5d81218cfdb0[redacted]f3d1bc6e4
A deploy token is used in place of a password when deploying, and cannot be used to log in. Tokens can be scoped to:
any artifact you have access to ('*')
any artifact within a group you have access to ('group-name/*')
a particular artifact you have access to ('group-name/artifact-name')
Create Deploy Token
Note: the token value will only be shown once after it is created, so be sure to copy it.
Token name
Laptop deploy token
Token scope
*
Single use?
Expires in
Never
Create Token
Existing Deploy Tokens
Show: disabled tokens? expired tokens? used single-use tokens?
Token Name | Scope | Single Use? | Expires | Created | Disabled | Last Used | Actions
~~rswan 3~~ | org.clojars.mindaslab.rswan/ org.clojars.mindaslab.rswan | no | Sep 5, 2025 16:59:21 +0000 | Aug 29, 2025 16:59:22 +0000 | Aug 29, 2025 17:12:44 +0000 | |
~~rswan second~~ | org.clojars.mindaslab.rswan/* | yes | | Aug 29, 2025 16:55:14 +0000 | Aug 29, 2025 17:12:47 +0000 | |
~~Clojars mindaslab~~ | org.clojars.mindaslab/* | no | | Aug 11, 2025 18:39:41 +0000 | Aug 11, 2025 18:43:38 +0000 | |
~~Macbook Pro~~ | | no | | Nov 14, 2023 16:33:11 +0000 | Nov 14, 2023 16:37:33 +0000 | |
Printline Deploy Token | org.clojars.mindaslab.printline/* | no | | Oct 1, 2025 16:50:16 +0000 | | | Disable Token
<single-use Fri Aug 29 2025 22:43:04 GMT+0530> | org.clojars.mindaslab.rswan/* | yes | | Aug 29, 2025 17:14:07 +0000 | | | Disable Token
rswan | org.clojars.mindaslab.rswan/* | no | | Aug 29, 2025 17:23:47 +0000 | | Sep 8, 2025 06:10:26 +0000 | Disable Token
~~<single-use Fri Aug 29 2025 22:43:04 GMT+0530>~~ | org.clojars.mindaslab.rswan/* | used | | Aug 29, 2025 17:13:09 +0000 | | Aug 29, 2025 17:14:51 +0000 |
~~rswan group~~ | org.clojars.mindaslab.rswan/* | no | | Aug 11, 2025 19:00:29 +0000 | Aug 29, 2025 17:12:50 +0000 | Aug 29, 2025 17:02:29 +0000 |
rswan | org.clojars.mindaslab/* | no | | Aug 11, 2025 18:44:15 +0000 | Aug 29, 2025 17:12:52 +0000 | Aug 11, 2025 18:58:38 +0000 |
~~Macbook Pro~~ | | no | | Nov 14, 2023 16:37:47 +0000 | Aug 11, 2025 17:32:56 +0000 | Nov 14, 2023 17:27:44 +0000 |
about status projects contribute changelog contact code security DMCA help API sitemap
Hosting costs sponsored by:
Shortcut
With in-kind sponsorship from:
1Password
Deps
resolving with dnsimple
fastly
Fastmail
StatusPage.io
uptime.com
remixed by BENDYWORKS
member project of clojurists together

Copy the token `Clojars···..` shown in the yellow strip. You will use this token to deploy the project.

33.3. Uploading to Clojars

Now, in your printline project, in `project.clj`, add this:

```
:repositories [["clojars" {:url
"https://clojars.org/groups/org.clojars.mindaslab.printline"
                           :sign-releases false}]]
```

This tells Clojars which namespace you are pushing your library to. Your `project.clj` should look like this:

```
(defproject printline "0.1.0-SNAPSHOT"
  :description "FIXME: write description"
  :url "http://example.com/FIXME"
  :license {:name "EPL-2.0 OR GPL-2.0-or-later WITH Classpath-exception-2.0"
            :url "https://www.eclipse.org/legal/epl-2.0/"}
  :dependencies [[org.clojure/clojure "1.11.1"]]
  :repl-options {:init-ns printline.core}
  :repositories [["clojars" {:url
"https://clojars.org/groups/org.clojars.mindaslab.printline"
                             :sign-releases false}]])
```

Now, let's change the project name from `printline` to `org.clojars.mindaslab.printline` in `project.clj`:

```
(defproject org.clojars.mindaslab.printline "0.1.0-SNAPSHOT"
  :description "FIXME: write description"
  :url "http://example.com/FIXME"
  :license {:name "EPL-2.0 OR GPL-2.0-or-later WITH Classpath-exception-2.0"
            :url "https://www.eclipse.org/legal/epl-2.0/"}
  :dependencies [[org.clojure/clojure "1.11.1"]]
  :repl-options {:init-ns printline.core}
  :repositories [["clojars" {:url
"https://clojars.org/groups/org.clojars.mindaslab.printline"
                             :sign-releases false}]])
```

Now, in the project root directory, run this command:

```
$ lein deploy clojars
```

It will prompt you for username, provide it.

```
$ lein deploy clojars
WARNING: please set :description in project.clj.
WARNING: please set :url in project.clj.
No credentials found for clojars
See `lein help deploying` for how to configure credentials to avoid prompts.
Username: mindaslab
```

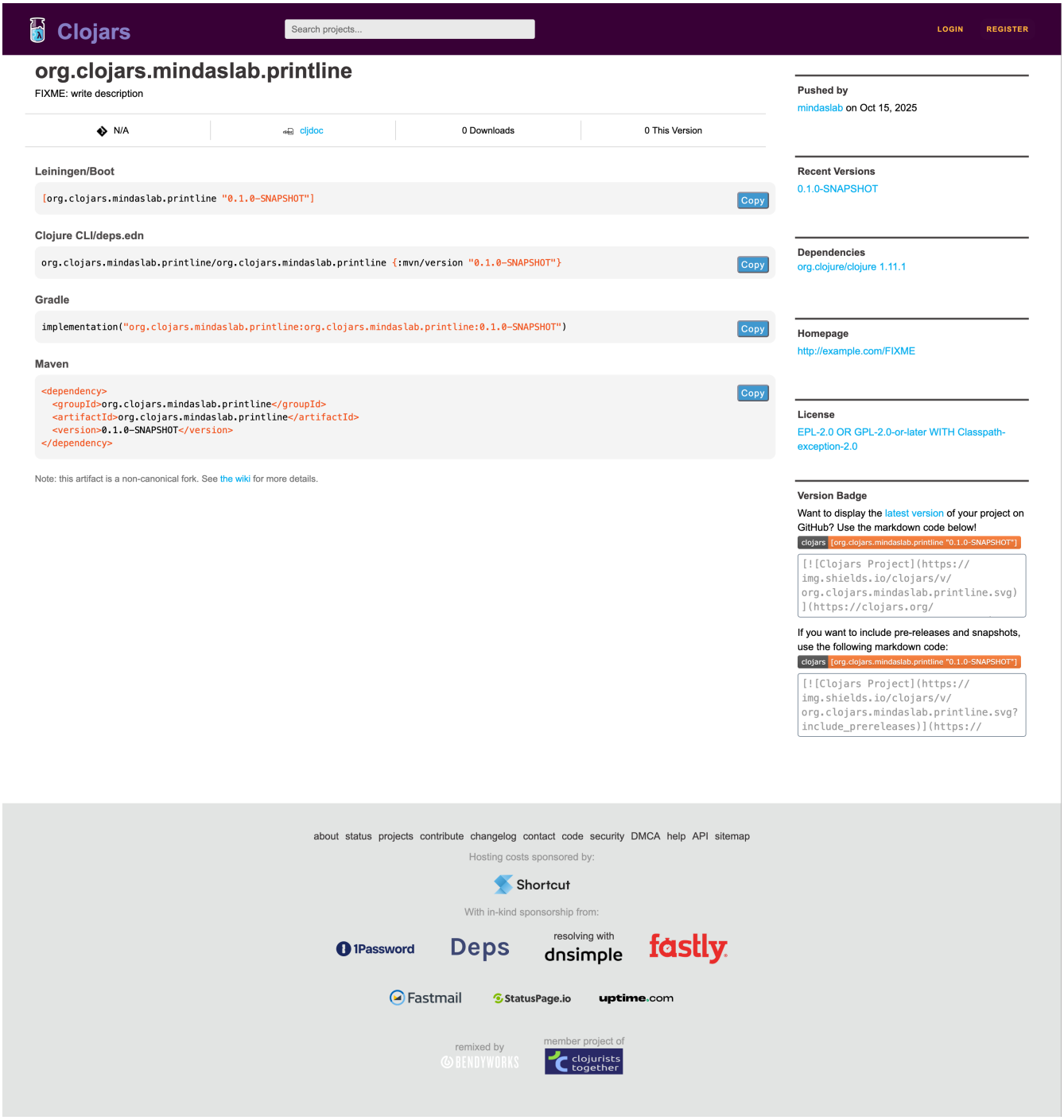
Then it will prompt you for password, provide the token you obtained from Clojars.

```
 lein deploy clojars
WARNING: please set :description in project.clj.
WARNING: please set :url in project.clj.
No credentials found for clojars
See `lein help deploying` for how to configure credentials to avoid prompts.
```

```
Username: mindaslab
Password:
Created
/Users/mindaslab/author/clojure/projects/printline/target/org.clojars.mindaslab.printl
ine-0.1.0-SNAPSHOT.jar
Wrote /Users/mindaslab/author/clojure/projects/printline/pom.xml
Could not find metadata
org.clojars.mindaslab.printline:org.clojars.mindaslab.printline:0.1.0-SNAPSHOT/maven-
metadata.xml in clojars (https://repo.clojars.org/)
Sending org/clojars/mindaslab/printline/org.clojars.mindaslab.printline/0.1.0-
SNAPSHOT/org.clojars.mindaslab.printline-0.1.0-20251015.115436-1.jar (9k)
    to https://repo.clojars.org/
Sending org/clojars/mindaslab/printline/org.clojars.mindaslab.printline/0.1.0-
SNAPSHOT/org.clojars.mindaslab.printline-0.1.0-20251015.115436-1.pom (2k)
    to https://repo.clojars.org/
Could not find metadata
org.clojars.mindaslab.printline:org.clojars.mindaslab.printline/maven-metadata.xml in
clojars (https://repo.clojars.org/)
Sending org/clojars/mindaslab/printline/org.clojars.mindaslab.printline/0.1.0-
SNAPSHOT/maven-metadata.xml (1k)
    to https://repo.clojars.org/
Sending org/clojars/mindaslab/printline/org.clojars.mindaslab.printline/maven-
metadata.xml (1k)
    to https://repo.clojars.org/
```

A few seconds later, the library is deployed.

Now, you can visit https://clojars.org/org.clojars.mindaslab.printline, and Clojars tells you how to use it.

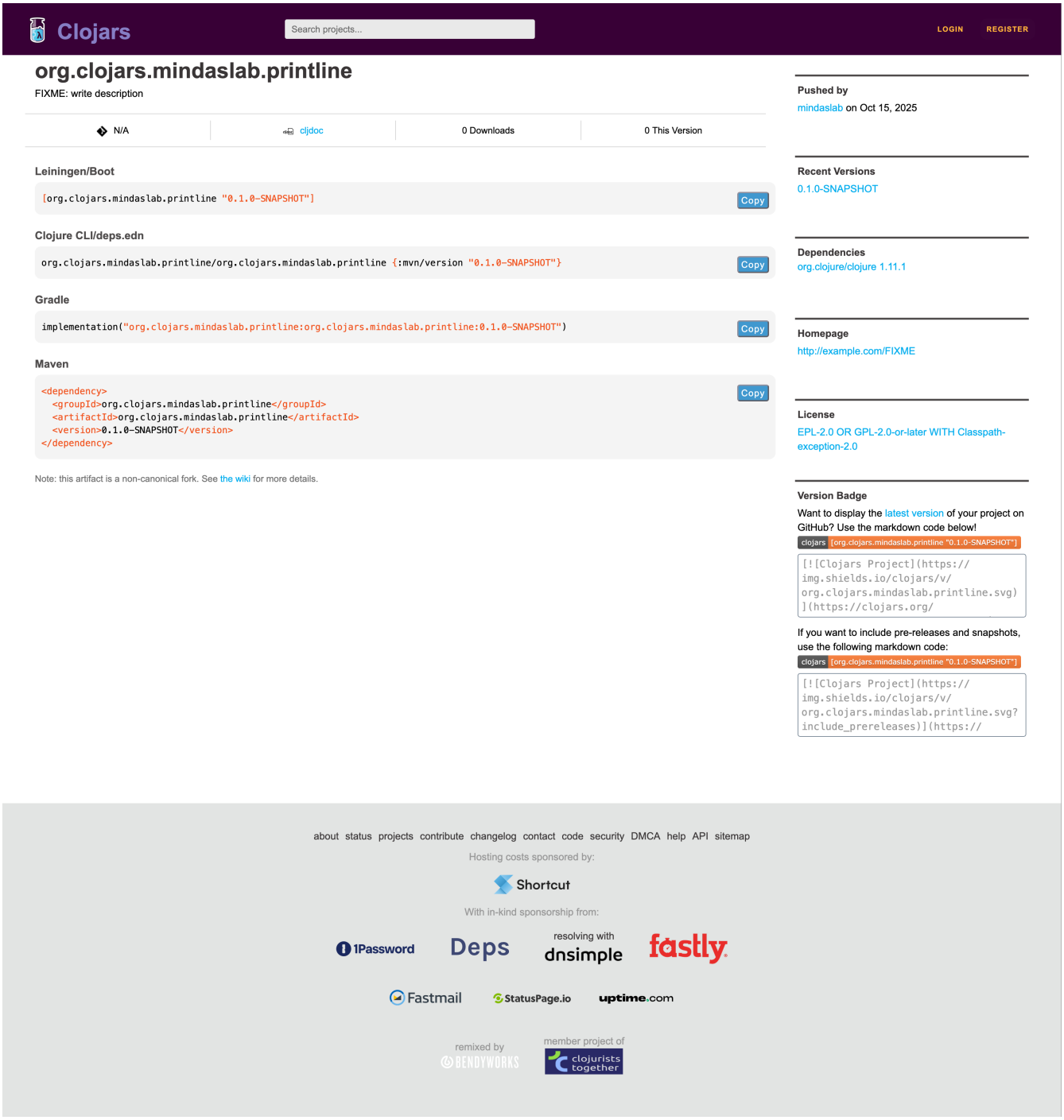


33.4. Using Your Library

Get code for this section here https://gitlab.com/clojure-book/try_printline

In this section, let's see how to use our library. Let's create a new project called `try_printline`.

Copy the dependency `[org.clojars.mindaslab.printline "0.1.0-SNAPSHOT"]` shown on the page: https://clojars.org/org.clojars.mindaslab.printline



Now let's create a new Leiningen project called `try_printline`.

```
$ lein new try_printline
```

In `project.clj`, add `[org.clojars.mindaslab.printline "0.1.0-SNAPSHOT"]` to the `:dependencies` vector. It should look like this:

```
(defproject try_printline "0.1.0-SNAPSHOT"
  :description "FIXME: write description"
  :url "http://example.com/FIXME"
  :license {:name "EPL-2.0 OR GPL-2.0-or-later WITH Classpath-exception-2.0"
            :url "https://www.eclipse.org/legal/epl-2.0/"}
  :dependencies [[org.clojure/clojure "1.11.1"]
```

```
                 [org.clojars.mindaslab.printline "0.1.0-SNAPSHOT"]]
  :repl-options {:init-ns try-printline.core})
```

Jack into the `try_printline` project and change the file `src/try_printline/core.clj` to have this content:

```
(ns try-printline.core
  (:require [printline.core :as pl]))


(pl/print-line "*")

(pl/print-line 30)

(pl/print-line "$", 40)
```

See how we are requiring `printline.core` in this statement `(:require [printline.core :as pl])`.

Run the following code:

```
(ns try-printline.core
  (:require [printline.core :as pl]))
```

It should return `nil`. Now run:

```
(pl/print-line "*")
```

You should see the following output in the REPL:

```
; ********************************************************************************
nil
```

Run:

```
(pl/print-line 30)
```

You should see this:

```
; ------------------------------
nil
```

And finally run:

```
(pl/print-line "$", 40)
```

You should see this:

```
; $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
nil
```

So we have successfully created a library, added it to Clojars, required it in our project, and used it. Happy publishing to Clojars!!

[1] https://calva.io/jack-in-guide/

Chapter 34. Metadata

Get the source for this section here https://yu7.in/XkFT5d

Watch the video for this section here https://yu7.in/5U0vRr

In Clojure, there are two ways to declare a function private: one with `defn-`, as shown:

```
(defn- private-function []
  "private function")
```

Or you can use the `defn` with the metadata as shown:

```
(defn ^:private private-function []
  "private function")
```

Metadata is data you can assign to a definition so that the compiler, or the program that uses the definition, can get hints about it. As you have seen with the `^:private` metadata, it is a boolean value that, when set to `true`, prevents the function from being accessed from other namespaces.

Let's dive deeper into metadata in this section.

In the code below, we are defining a variable named `some-var-with-meta`, and we are assigning the metadata `^:boo` to it.

```
(def ^:boo some-var-with-meta 7)
;; => #'user/some-var-with-meta
```

Now let's declare another variable called `some-var` without any metadata.

```
(def some-var 7)
;; => #'user/some-var
```

Let's compare these two variables.

```
(= some-var some-var-with-meta)
;; => true
```

Though metadata is assigned to `some-var-with-meta`, it is still equal to `some-var`. Metadata in Clojure does not affect the normal operation of the variable.

Now let's extract metadata of `some-var-with-meta`:

```
(meta #'some-var-with-meta)
;; => {:boo true, :line 1, :column 1, :file
"/Users/mindaslab/author/clojure/code/meta_data.clj", :name some-var-with-meta, :ns
#object[clojure.lang.Namespace 0xf7f1972 "user"]}
```

As you can see above, we get the metadata as a map, where the symbol `:boo` is `true`. You might wonder what the `#'` in `#'some-var-with-meta` means. It is a reader macro that refers to the variable `some-var-with-meta`, rather than its value `7`.

It's not the case that only one piece of metadata can be assigned to a definition; you can assign a map with lots of keys and values:

```
(def ^{:a 1 :b 2 :c 3} lots-of-meta 42)
;; => #'user/lots-of-meta
```

Now when we query the metadata of `lots-of-meta`, we get:

```
(meta #'lots-of-meta)
;; => {:a 1, :b 2, :c 3, :line 13, :column 1, :file
"/Users/mindaslab/author/clojure/code/meta_data.clj", :name lots-of-meta, :ns
#object[clojure.lang.Namespace 0xf7f1972 "user"]}
```

Note apart from `:a`, `:b`, and `:c` there are other keys in the map, but we will not go into detail about them.

In previous examples, calling `meta` gave a lot of information about the variable, but declaring a variable with `with-meta` avoids a lot of clutter:

```
(def my-list (with-meta '(1 2 3) {:secret "meta"}))
;; => #'user/my-list
```

In the above example we define a variable:

```
(def my-list)
```

Then we use the `with-meta` function:

```
(def my-list (with-meta ....))
```

Add the definition value as first argument to `with-meta`

```
(def my-list (with-meta '(1 2 3) ....))
```

Add the metadata as second argument to `with-meta`:

```
(def my-list (with-meta '(1 2 3) {:secret "meta"}))
```

That's it.

Now let's check the value of `my-list`:

```
my-list
;; => (1 2 3)
```

Now let's check the metadata of `my-list`:

```
(meta my-list)
;; => {:secret "meta"}
```

It's cleaner while querying metadata.

Have you noticed? We use `meta` on `my-list` and not on `#'my-list`. The reason is that the function `with-meta` attaches metadata to the value of `my-list` (which is `'(1 2 3)`) and not to the entity that holds the name `my-list` and its value `'(1 2 3)`.

We have seen before that `^:private` can be attached to a function, making it private and only accessible in the defined namespace. In a similar way, any keyword can be attached as metadata to a Clojure function. Below we attach `{:something true}` to a function:

```
(defn ^:something my-function []
  "some function")
;; => #'user/my-function
```

We call `my-function`:

```
(my-function)
;; => "some function"
```

It works as expected. But as you can see below, when we query its metadata, the keyword `:something` has the value `true` attached to it.

```
(meta #'my-function)
;; => {:something true, :arglists ([]), :line 29, :column 1, :file
"/Users/mindaslab/author/clojure/code/meta_data.clj", :name my-function, :ns
#object[clojure.lang.Namespace 0xf7f1972 "user"]}
```

Docstrings are metadata too, the below function has a docstring.

```
(defn function-with-doc
  "This is a function with doc string"

  []
  (println "some function"))
;; => #'user/function-with-doc
```

Now, if you query the meta `(meta #'function-with-doc)` and pull out the value associated with the keyword `:doc`, as shown below:

```
(:doc (meta #'function-with-doc))
;; => "This is a function with doc string"
```

You will get the docstring as output.

The same effect can be achieved by setting the keyword `:doc` as metadata for a function, as shown below.

```
(defn ^{:doc "This is another function with doc string"} another-function-with-doc

  []
  (println "some function"))
;; => #'user/another-function-with-doc

(:doc (meta #'another-function-with-doc))
;; => "This is another function with doc string"
```

A map can be assigned as metadata to a function, with lots of keywords and values, as shown below.

```
(defn ^{:a 1 :b 2 :c 3} lots-of-meta-my-function []
  "some function")
;; => #'user/los-of-meta-my-function
```

When we query its `meta`, we get those keywords and values, along with other metadata Clojure sets implicitly, as shown below.

```
(meta #'lots-of-meta-my-function)
;; => {:ns #object[clojure.lang.Namespace 0xf7f1972 "user"], :name los-of-meta-my-
function, :file "/Users/mindaslab/author/clojure/code/meta_data.clj", :column 1, :c 3,
:line 52, :b 2, :arglists ([]), :a 1}
```

Bibliography

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- Practicalli https://practical.li/
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- The Joy of Clojure https://amzn.to/3hOwJtN
- Mastering Clojure Macros https://amzn.to/3KWoXdF
- Clojure Script Unravelled https://funcool.github.io/clojurescript-unraveled/

Many hackers swear by LISP, and just like any other programmer coming from OOPS background I was skeptical about functional programming. When I started learning it, it wasn't straight forward (for an OOP developer), but I persisted and when I reached what's called REPL driven development I was blown away.

Clojure is a dialect of LISP, and it was smartly designed to be hosted and not compiled, which means that when you learn it, you can target multiple platforms like Java runtime, Common Language Runtime, JavaScript and Dart platforms, hence your job potential will be huge if you master it.

Clojure and all LISP based languages, surprisingly has only one syntax, which makes it simple and unimaginably powerful, and hence makes it easier to learn compared to other languages, and hence I feel it could be great first programming language for many.

Join me in this wonderful journey to learn a dialect of a language which refuses to die and rises like phoenix.

- Karthikeyan A K